METEOROLOGY OF AUSTRALIA
COMMONWEALTH BUREAU OF METEOROLOGY

# THE CLIMATE AND WEATHER OF AUSTRALIA


BY

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## PREFATORY NOTE.

In submitting this small work to the public, we venture to express the hope that it may prove acceptable as being the first effort in the nature of a text-book that has been published on Australian Meteorology.

Our acknowledgments are due to the staff individually and collectively for their ready co-operation in the compilation of data on which the whole subject-matter is based.

Finally, we should like to remind our readers of the imperishable debt of gratitude we all owe to those revered pioneers in Australian Meteorology, H. C. Russell, Esq., B.A., C.M.G., F.R.S.; R. L. J. Ellery, Esq., C.M.G., F.R.S.; and Sir Chas. Todd, M.A., F.R.S., whose strenuous and untiring labours contributed so largely towards bringing our knowledge of Australian climatology to its present advanced stage at a comparatively early age in our national history.

H. A. HUNT.
GRIFFITH TAYLOR.
E. T. QUAYLE.

# LIST OF MAPS AND CHARTS.

# CLIMATE AND WEATHER OF AUSTRALIA.

## CONTENTS.

# CLIMATE AND WEATHER OF AUSTRALIA.

## I.—SIZE OF CONTINENT AND EFFECT ON CLIMATIC VARIATION.

Australia extends both sides of the Tropic of Capricorn from 10° S. latitude to 45° S. latitude. The greater portion lies south of the Tropic, and hence has a generally temperate climate. At the same time the range of 35° in latitude implies a very great difference between the north and south of the Continent, which justifies the remark that Port Darwin has a climate resembling that of Trinidad, while Tasmania has a typically cool, moist climate like that of England.

In addition to these extremes due to difference of latitude, there are many diversities due to the great breadth of the Continent along the tropic. Here Australia is 2,400 miles from west to east, so that a great portion of its surface lies remote from the influences of the sea. In this respect Australia differs markedly from the other southern land masses; for South America lies in a typically meridional direction and South Africa is only 1,400 miles across at the Southern Tropic. This factor of location is of extreme importance, for the climatic regions into which any large area can be subdivided depend essentially on the "lie of the land" with respect to the surrounding oceans, dominant winds, and other permanent influences.

In area Australia is about three-quarters that of Europe and contains (with Tasmania) 2,974,581 square miles. It is characterized by a very uniform outline, and by a lower average elevation than that of any other continent.

Both of these factors make for simplicity in the meteorology, for there are no tongues of water penetrating far into the interior, modifying the climate as does the Mediterranean in the Euro-African land mass. Moreover, Australia is absolutely devoid of large freshwater areas, and the salty lakes of Southern Australia do not appear to affect the climate of the surrounding area.

The average elevation of Australia is probably somewhat under 1,000 feet. Although, as will be seen in Section VII., the more important positive land forms such as the Darling, Macdonnell, and Flinders Ranges, the Blue Mountains and Australian Alps have a great effect on the *local* distribution of rain, they do not act as primary agents in determining the climates of Australia. For instance, there is no such marked division as in the windward wet province of Western U.S.A., or the intramontane dry area of the Southern Rockies. As will be seen, however, similar types on a smaller scale are to be recognised in Australia (*vide* Section VII.).

Finally, it may be mentioned that the two chief gaps in the oval outline of the Continent—the Gulf of Carpentaria and the Great Australian Bight—would appear to control the movement of the cyclonic disturbances to some extent, as will be noticed later.

## II.—THE SEASONS AND THE MARCH OF THE TEMPERATURE.

The sun reaches the southern limit of his annual movement on 22nd December or thereabouts. In consequence of a slight lag in the heating effect, January is, in general, the hottest month in Australia. The year, therefore, may be divided as follows:—

*Summer.*—December, January, and February.

*Autumn.*—March, April, and May.

*Winter.*—June, July, and August.

*Spring.*—September, October, and November.

Since Australia extends over so many degrees of latitude, its northern area obviously comes under the influence of equatorial conditions, where the four seasons are not so well marked as, for instance, in Europe. Here the major divisions are the wet and dry seasons. But there is a difference of 10° between the mean temperatures of January and July, and there is a remarkable dissimilarity between the muggy conditions in January (when the heaviest rain for the year falls) and the dry heat of July.

In the south the division of the year into four seasons is well marked, though over the greater portion of the year definite wet and dry periods are still noticeable.

### The March of Temperature.

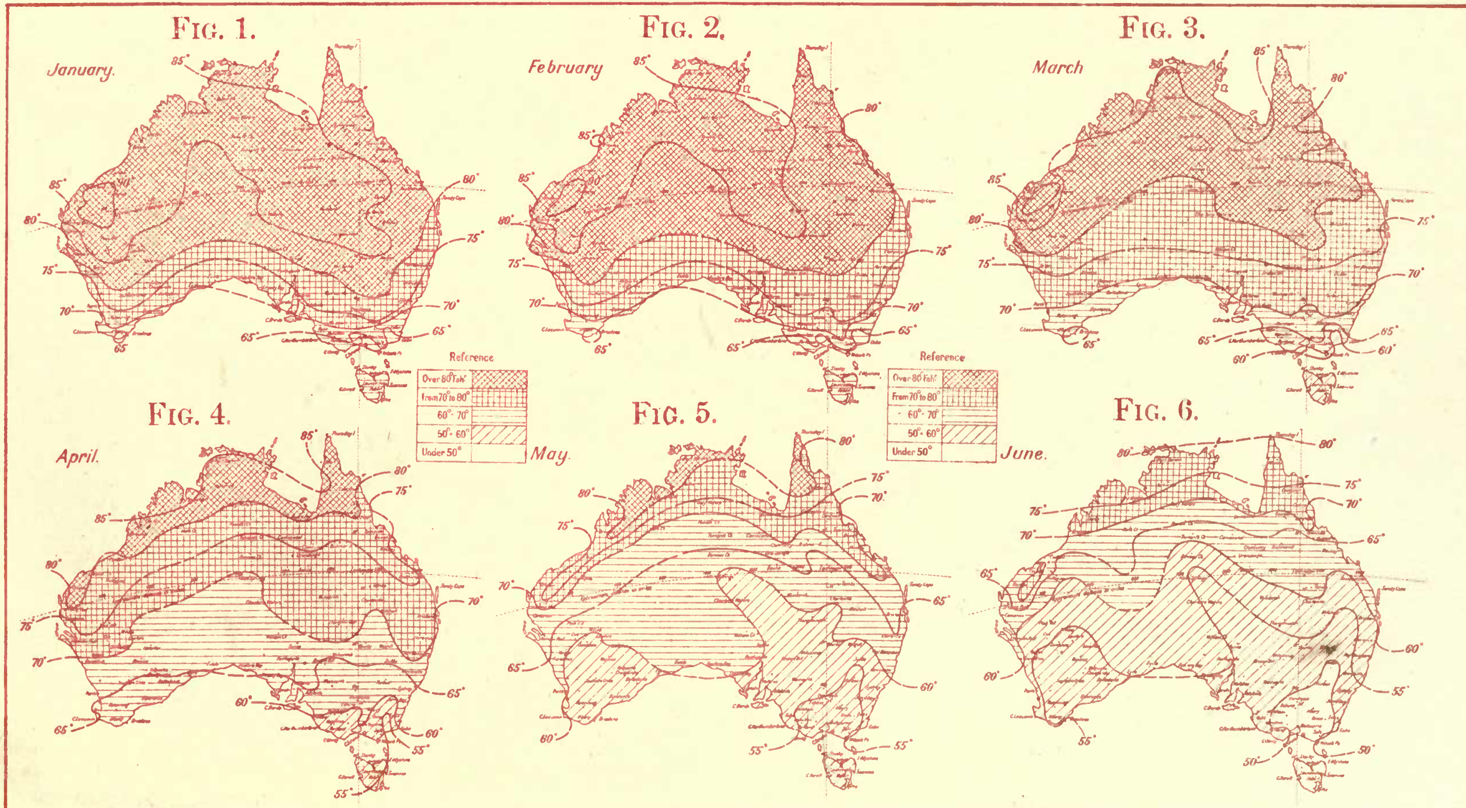
A study of the mean monthly temperature charts shows a marked control of temperature by latitude, modified, however, by well-defined variations. These latter may be classed as—

Alpine Cool Loops.

Hinterland Hot Loops.

Let us start in *August*, when the sun is moving south and approaching the equinox. The isotherms run almost due east and west, the hottest region being the north-west coast. A cold loop covering the south-east corner of Australia is due to the presence of the Australian Alps and Tablelands of Eastern New South Wales. This factor brings the 50° isotherm nearly to Dubbo, New South Wales. In *September*, this region of elevation is warming and the loop has disappeared, but two hinterland loops have appeared in the north—one in the north-west, behind the Pearling Coast (Cossack and Condon), and the other along the N.E. Queensland Coast—whereby the 70° isotherm is carried far south to Rockhampton. As the months advance, the north-west loop becomes a closed heated area over the Pilbara Goldfield (Nullagine, &c.), where all the summer (December, January, February, and March) a mean temperature of 90° is experienced.

# MEAN MONTHLY TEMPERATURE.



# MEAN MONTHLY TEMPERATURE.

Fig. 7.

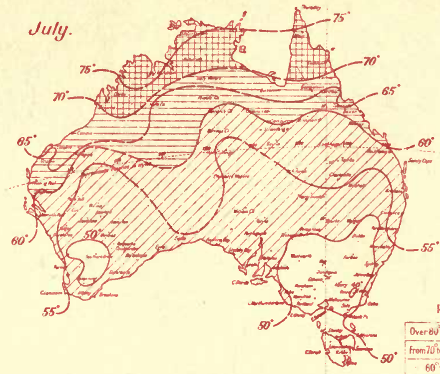



Fig. 8.

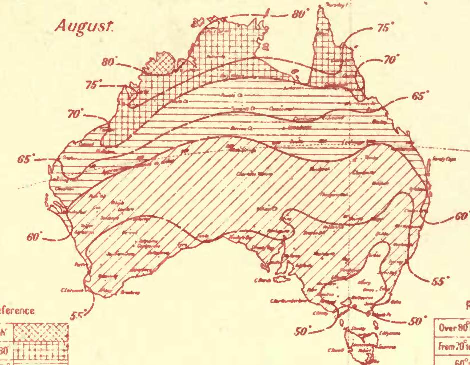
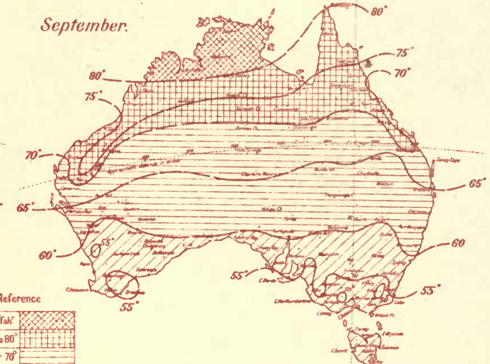



Fig. 9.




Reference

| | |
|---|---|
| Over 80° Fah.t | |
| From 70° to 80° | |
| 60°- 70° | |
| 50°- 60° | |
| Under 50° | |

Fig. 10.

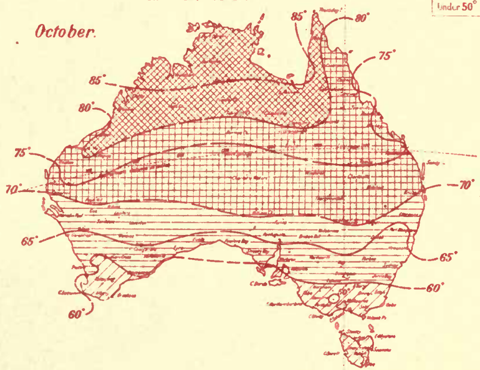



Fig. 11.

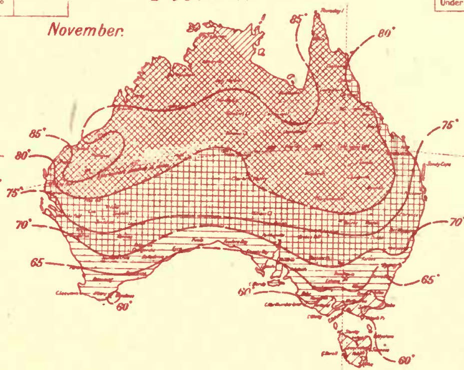
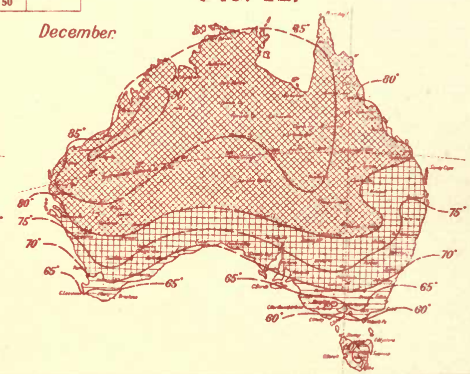
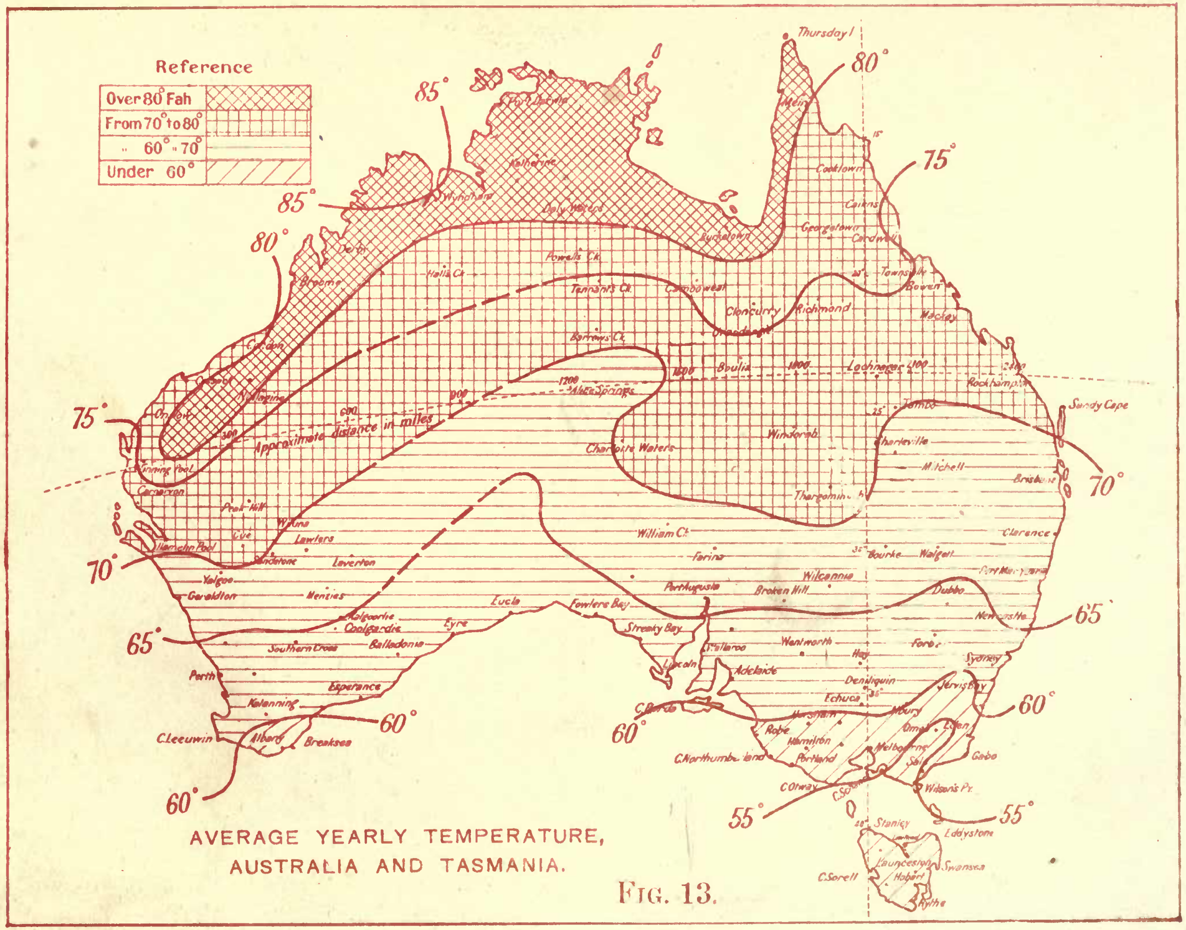



Fig. 12.




Reference

| | |
|---|---|
| Over 80° Fah.t | |
| From 70° to 80° | |
| 60°- 70° | |
| 50°- 60° | |
| Under 50° | |




AVERAGE YEARLY TEMPERATURE, AUSTRALIA AND TASMANIA.

FIG. 13.

The north-east loop moves gradually westward and southward during spring and summer, forming finally a broad warm loop running down from the Gulf to South-west Queensland. This trend of the loop is no doubt largely due to the monsoon winds from the north, which characterize the front of the cyclonic system usually dominating North-west Australia in summer.

In April and later, the Queensland loop shrinks as the land areas cool, while the Kosciusko Alpine loop (in the S.E.) advances to its maximum in July.

Across Central and South-western Australia the isotherms move equatorwards in winter, and retreat in summer without losing their east-west direction. The 75° isotherm moves about 1,200 miles north (as winter approaches) from January to July, the cooling being quickest in April and May. (It must be noticed that our meteorological knowledge of the west centre of the continent is very meagre, and more complete data may indicate looped isotherms in the remaining quadrant of the continent, though the topography would not seem to favour such a condition.)

Details of the distribution of temperature, especially with regard to the State capitals, will be of interest.

January is the hottest and July the coldest month.

The highest temperatures are recorded over the north-western portion of Western Australia (see Fig. 14), where the maximum shade temperatures have exceeded 100° on 64 consecutive days and 90° on 150 consecutive days, the mean temperature of the hottest month being 90° and the mean temperature of the coldest 65°.

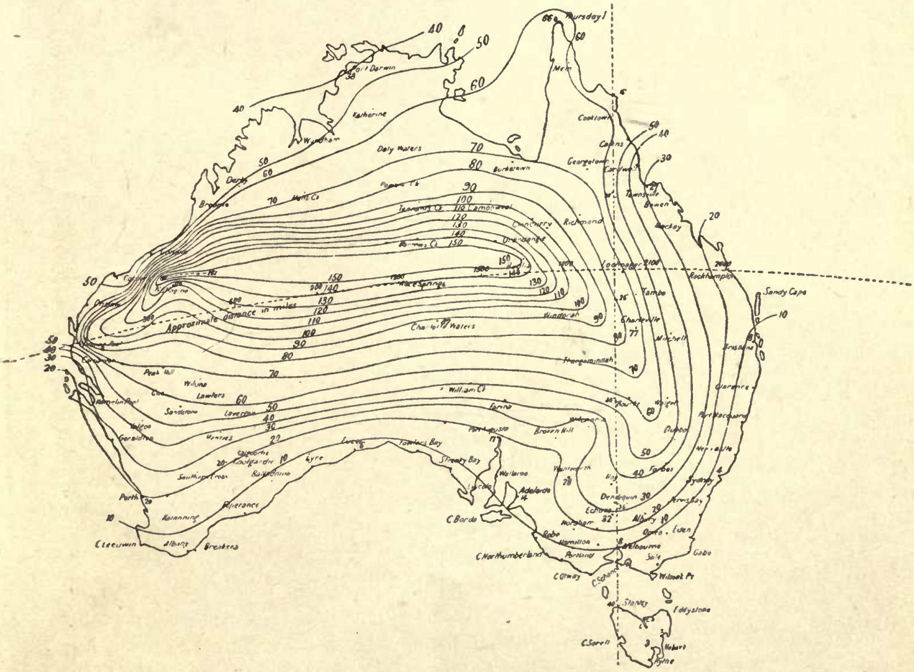



FIG. 14.
Chart showing maximum number of consecutive days with temperature reaching 90° for any one hot spell.

The coldest portion of Australia is the Australian Alps situated in North-eastern Victoria and South-eastern New South Wales, where the mean shade temperatures range from 65°, in January, to 40° Fah., in July. During exceptionally dry summers the temperatures in the interior reach, and occasionally exceed, 120°, and the same areas during the winter months are subject to ground frosts.

Taking Australia as a whole, the extremes of temperature annually, seasonally, and daily are less than those experienced in any of the other continents, and the mean temperatures prevailing are generally lower than for corresponding latitudes in the other continental land areas of the Globe. These features are due mainly to insularity and the comparative absence of physiographical extremes.

The following table gives the monthly, seasonal, and annual means and extremes of temperature for the Australian capitals :—

*Mean Monthly Temperatures and Rainfall of the Australian Capitals.*

| — | PERTH. | | | | | ADELAIDE. | | | | | BRISBANE. | | | | | SYDNEY. | | | | | MELBOURNE. | | | | | HOBART. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Means. | | Ex-tremes. | | | Means. | | Ex-tremes. | | | Means. | | Ex-tremes. | | | Means. | | Ex-tremes. | | | Means. | | Ex-tremes. | | | Means. | | Ex-tremes. | | |
| | Max. | Min. | Max. | Min. | Rainfall. | Max. | Min. | Max. | Min. | Rainfall. | Max. | Min. | Max. | Min. | Rainfall. | Max. | Min. | Max. | Min. | Rainfall. | Max. | Min. | Max. | Min. | Rainfall. | Max. | Min. | Max. | Min. | Rainfall. |
| | ° | ° | ° | ° | | ° | ° | ° | ° | | ° | ° | ° | ° | | ° | ° | ° | ° | | ° | ° | ° | ° | | ° | ° | ° | ° | |
| December .. .. | 81 | 60 | 108 | 48 | 54 | 83 | 59 | 114 | 43 | 94 | 85 | 67 | 106 | 57 | 512 | 77 | 63 | 107 | 49 | 260 | 75 | 54 | 111 | 40 | 230 | 70 | 51 | 105 | 38 | 193 |
| January .. .. | 84 | 63 | 107 | 51 | 33 | 87 | 62 | 116 | 45 | 73 | 85 | 69 | 109 | 59 | 666 | 78 | 65 | 108 | 51 | 367 | 78 | 57 | 111 | 42 | 185 | 72 | 53 | 105 | 40 | 180 |
| February .. .. | 85 | 63 | 107 | 48 | 31 | 86 | 62 | 114 | 46 | 60 | 85 | 68 | 102 | 59 | 663 | 77 | 65 | 101 | 49 | 470 | 78 | 57 | 109 | 40 | 174 | 72 | 53 | 104 | 39 | 145 |
| Summer .. | 83 | 62 | 108 | 48 | 118 | 85 | 61 | 116 | 43 | 227 | 85 | 68 | 109 | 57 | 1841 | 77 | 64 | 108 | 49 | 1097 | 77 | 56 | 111 | 40 | 589 | 71 | 52 | 105 | 38 | 518 |
| March .. .. | 82 | 61 | 104 | 46 | 71 | 81 | 59 | 108 | 45 | 106 | 82 | 66 | 97 | 56 | 620 | 75 | 63 | 103 | 49 | 507 | 75 | 55 | 105 | 37 | 218 | 68 | 51 | 99 | 36 | 165 |
| April .. .. .. | 76 | 57 | 100 | 42 | 165 | 73 | 55 | 98 | 40 | 187 | 79 | 61 | 95 | 49 | 364 | 71 | 58 | 89 | 45 | 524 | 68 | 51 | 94 | 35 | 232 | 63 | 47 | 90 | 30 | 180 |
| May .. .. .. | 69 | 52 | 90 | 40 | 488 | 65 | 50 | 88 | 37 | 274 | 74 | 55 | 89 | 41 | 292 | 65 | 52 | 83 | 40 | 495 | 62 | 47 | 84 | 31 | 215 | 57 | 43 | 77 | 29 | 191 |
| Autumn .. | 76 | 57 | 104 | 40 | 724 | 73 | 55 | 108 | 37 | 567 | 78 | 61 | 97 | 41 | 1276 | 70 | 58 | 103 | 40 | 1526 | 68 | 51 | 105 | 31 | 665 | 63 | 47 | 99 | 29 | 536 |
| June .. .. .. | 64 | 49 | 77 | 37 | 651 | 60 | 47 | 76 | 32 | 310 | 69 | 50 | 81 | 36 | 262 | 60 | 48 | 75 | 38 | 518 | 57 | 44 | 72 | 28 | 211 | 53 | 41 | 75 | 28 | 222 |
| July .. .. .. | 62 | 47 | 74 | 36 | 644 | 59 | 44 | 74 | 32 | 266 | 68 | 48 | 83 | 36 | 233 | 59 | 46 | 75 | 36 | 468 | 55 | 42 | 68 | 27 | 186 | 52 | 39 | 72 | 27 | 210 |
| August .. .. | 64 | 48 | 80 | 35 | 555 | 62 | 46 | 85 | 32 | 250 | 71 | 50 | 87 | 37 | 235 | 62 | 47 | 82 | 37 | 329 | 59 | 43 | 77 | 28 | 181 | 55 | 41 | 82 | 27 | 183 |
| Winter .. .. | 63 | 48 | 80 | 35 | 1850 | 60 | 46 | 85 | 32 | 826 | 69 | 49 | 87 | 36 | 730 | 60 | 47 | 82 | 36 | 1315 | 57 | 43 | 77 | 27 | 578 | 53 | 40 | 82 | 27 | 615 |
| September .. .. | 66 | 50 | 86 | 39 | 337 | 66 | 48 | 91 | 33 | 195 | 76 | 55 | 95 | 41 | 205 | 66 | 51 | 91 | 41 | 289 | 63 | 45 | 82 | 31 | 235 | 59 | 43 | 80 | 30 | 214 |
| October .. .. | 69 | 53 | 93 | 41 | 206 | 72 | 51 | 100 | 36 | 174 | 80 | 60 | 101 | 43 | 278 | 71 | 56 | 100 | 43 | 282 | 67 | 48 | 96 | 32 | 264 | 63 | 45 | 91 | 32 | 224 |
| November .. .. | 75 | 56 | 101 | 42 | 76 | 79 | 55 | 113 | 41 | 115 | 83 | 64 | 105 | 48 | 365 | 74 | 60 | 103 | 46 | 291 | 71 | 51 | 106 | 36 | 220 | 67 | 48 | 98 | 37 | 250 |
| Spring .. .. | 70 | 53 | 101 | 39 | 619 | 72 | 51 | 113 | 33 | 484 | 80 | 60 | 105 | 41 | 848 | 70 | 56 | 103 | 41 | 862 | 67 | 48 | 106 | 31 | 719 | 63 | 45 | 98 | 30 | 688 |
| Year .. .. | 73 | 55 | 108 | 35 | 3311 | 73 | 53 | 116 | 32 | 2104 | 78 | 60 | 109 | 36 | 4695 | 70 | 56 | 108 | 36 | 4800 | 67 | 49 | 111 | 27 | 2551 | 62 | 46 | 105 | 27 | 2357 |

NOTE.—Rainfall is in Points ; 100 Points = 1 inch.

Brisbane experiences the highest annual mean maximum temperature with 78°; Adelaide and Perth follow with 73°; Sydney, 70°; Melbourne, 67°; and Hobart, 62°. But the extremes take a different order. Adelaide comes first, with a maximum of 116°; Melbourne, 111°; Brisbane, 109°; Sydney and Perth, 108°; and Hobart, 105°.

The lowest shade temperatures recorded are as follows:—Melbourne, 27°; Hobart, 27°; Adelaide, 32°; Perth, 35°; Sydney and Brisbane, 36°.

## III.—GENERAL VARIATION IN PRESSURE.

At only a few important stations in each State are complete barometric data available for any length of time. These have unfortunately been taken out for differing times of the day.

The twelve monthly charts herewith are therefore only approximations, the data being as follows:—

| State. | Number of Stations. | Year's Record. | Time of Observations. |
|---|---|---|---|
| Western Australia .. | 34 | All over 12 years, except Balladonia (9), Wiluna (9), Cape Naturaliste (6), and Winning Pool (5) | 9 a.m. and 3 p.m. |
| South Australia .. | 6 | All over 15 years .. .. | 9 a.m. and 3 p.m. |
| Queensland .. | 10 | All over 10 years, except Boulia (9), Normanton (8), Cunnamulla (7), and Cooktown (9) | 9 a.m. |
| New South Wales | 12 | All over 15 years .. .. | 9 a.m. |
| Victoria .. .. | 10 | All over 15 years .. .. | 9 a.m., 3 p.m., 9 p.m. (reduced to hourly means) |
| Tasmania .. | 1 | Hobart, 40 years .. .. | 9 a.m. and 3 |

The general features of the *average* monthly isobars as shown on the charts will be briefly discussed; but in these charts the curves are necessarily much smoothed, and many interesting constant local characters can be better investigated from a much more detailed series prepared for *one* year. (This is done for 1910 in later paragraphs.) Some of the charts for the year are given in figures 29–31.

The annual fluctuations of mean barometric pressure for the State capital cities is given in the annexed graph (Fig. 28).

In *January* (midsummer) a depression of a monsoonal nature occupies North-west Australia. The Antarctic belt of lows reaches to the South Coast of Tasmania. The warm high land in the south-east appears to give rise to a col of low pressure separating anticyclonic foci over the Bight and over the North Tasman Sea. In *February*, the conditions remain much the same. In *March*, the northern low has moved off the continent to the north-west and the anticyclones have strengthened considerably over the two foci. In *April* a closed *high* is forming over the south-east of the continent, and elsewhere the isobars run across Australia from west to east.

# MEAN MONTHLY ISOBARS.

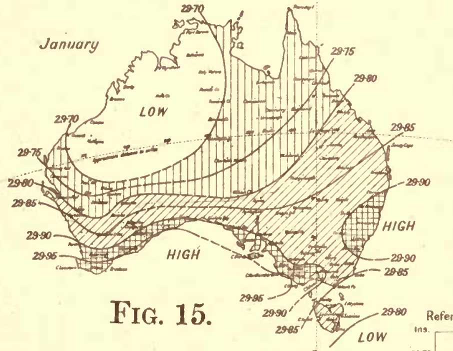



FIG. 15.

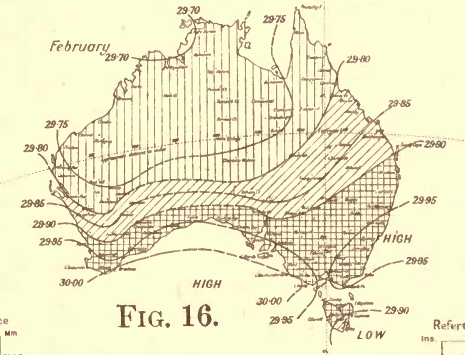



FIG. 16.

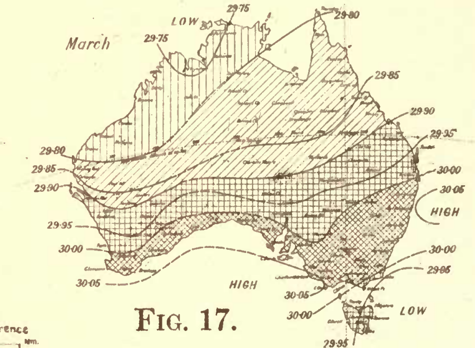
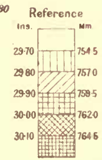



FIG. 17.



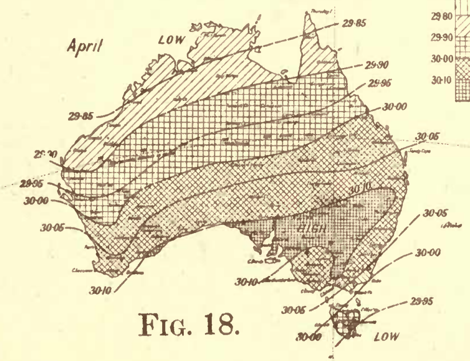




FIG. 18.

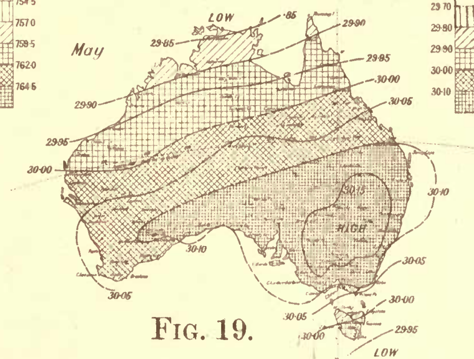
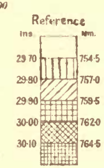



FIG. 19.



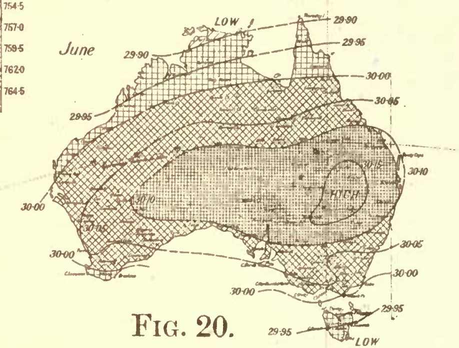




FIG. 20.

# MEAN MONTHLY ISOBARS.

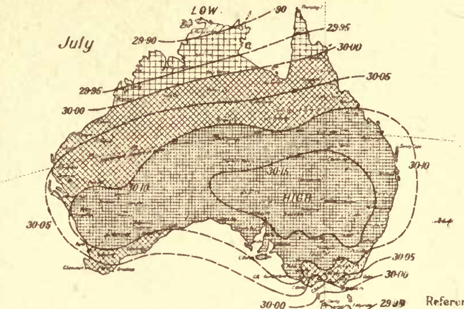
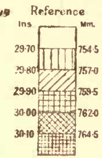



FIG. 21.



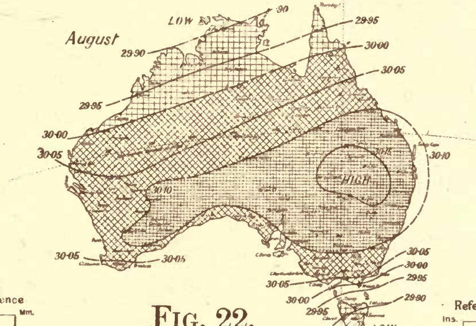
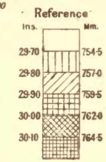




FIG. 22.



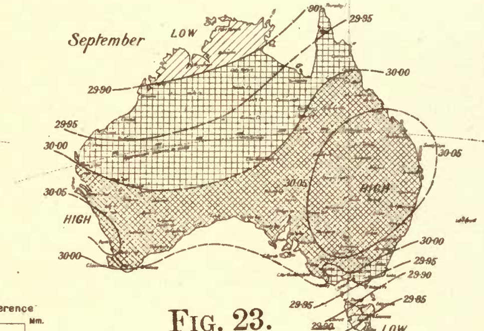




FIG. 23.

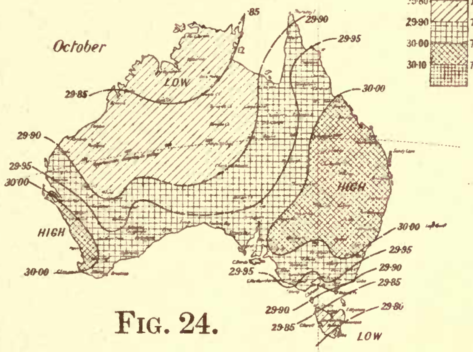



FIG. 24.

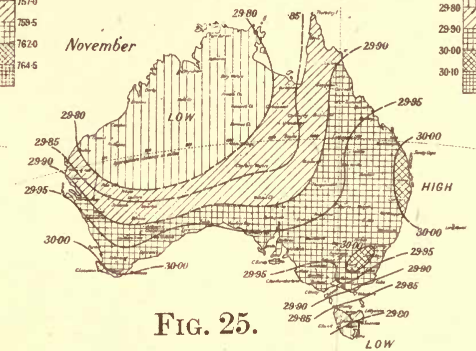



FIG. 25.

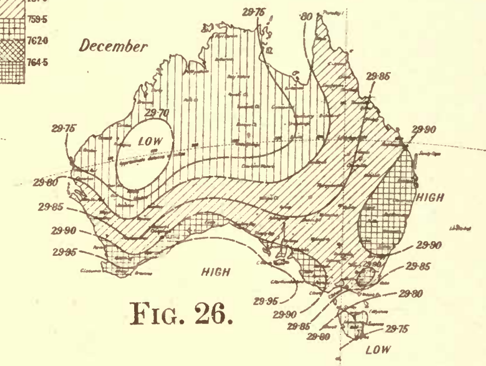



FIG. 26.

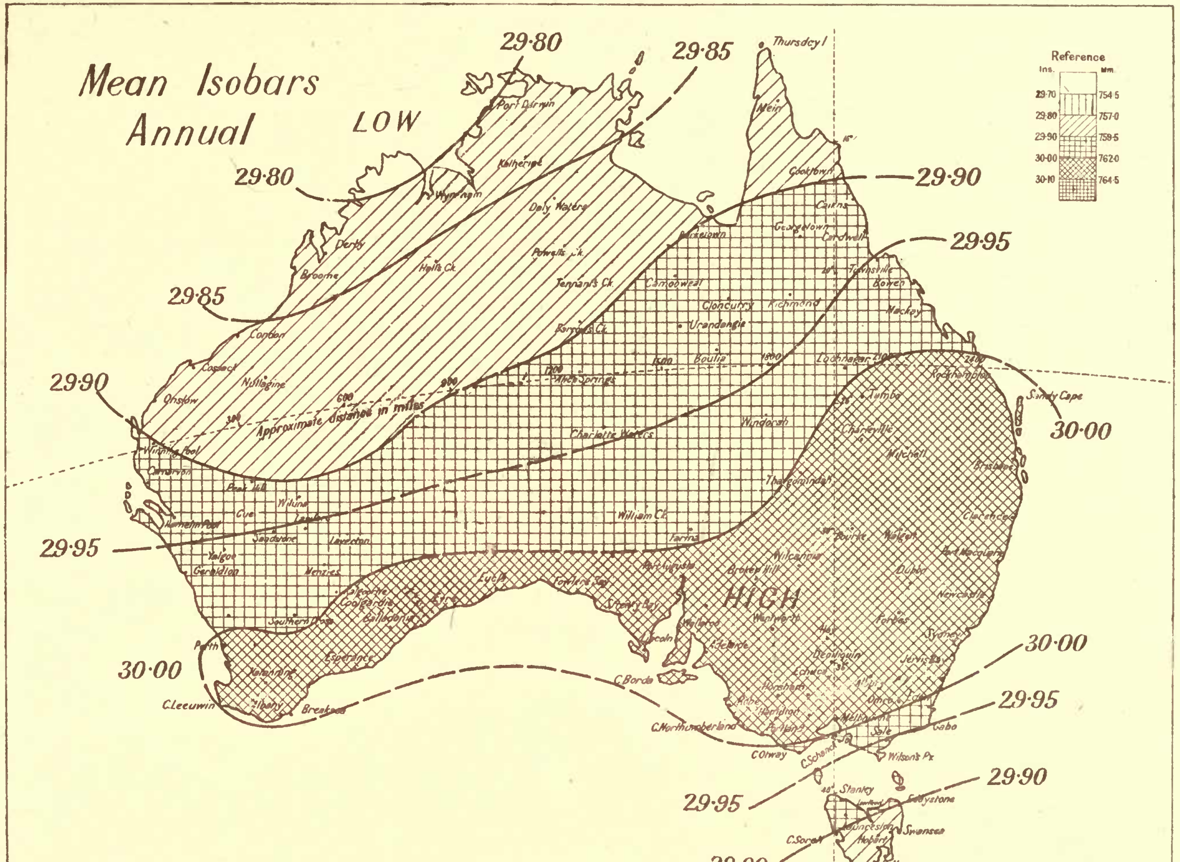
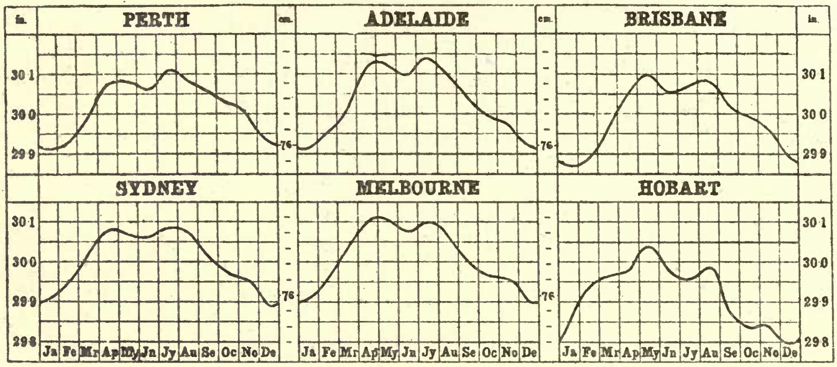

Mean Isobars
Annual
LOW
HIGH
29·80
29·85
29·90
29·95
30·00
Reference
Approximate distance in miles
Thursday I
Port Darwin
Derby
Broome
Hall's Ck.
Daly Waters
Tennant's Ck.
Cooktown
Cairns
Cardwell
Townsville
Bowen
Mackay
Rockhampton
Sandy Cape
Brisbane
Camooweal
Cloncurry
Richmond
Urandangie
Boulia
Alice Springs
Charlotte Waters
Windorah
Charleville
Mitchell
Thargomindah
William Ck.
Farina
Bourke
Walgett
Wilcannia
Broken Hill
Port Augusta
Dubbo
Newcastle
Forbes
Sydney
Jervis Bay
Wentworth
Adelaide
Deniliquin
Echuca
Horsham
Melbourne
Sale
Gabo
Wilson's Pt.
C. Otway
C. Northumberland
C. Borda
Streaky Bay
Fowlers Bay
Eucla
Coolgardie
Esperance
Albany
C. Leeuwin
Perth
Geraldton
Yalgoo
Cue
Carnarvon
Onslow
Nullagine
Condon
Menzies
Laverton
Stanley
Launceston
Hobart
Swansea
C. Sorell
Eddystone

FIG. 27.

GRAPHS SHEWING ANNUAL FLUCTUATIONS OF MEAN BAROMETRIC PRESSURE FOR THE STATE CAPITAL CITIES.




EXPLANATION OF THE GRAPHS OF BAROMETRIC PRESSURE.—On the above graphs the lines representing the yearly fluctuation of barometric pressure at the State capital cities are means for long periods, and are plotted from the Climatological Tables given hereinafter. The pressures are shewn in inches on about 2½ times the natural scale, and the corresponding pressures in centimetres are also shewn in the two inner columns, in which each division represents one millimetre.

INTERPRETATION OF THE BAROMETRIC GRAPHS.—Taking the Brisbane graph for purposes of illustration, it will be seen that the mean pressure on 1st January is about 29.88 inches, and there are maxima in the middle of May and August of about 30.10 and 30.08 respectively. The double maxima appear clearly on each graph.

FIG. 28.

MEAN PRESSURE, APRIL, 1910.

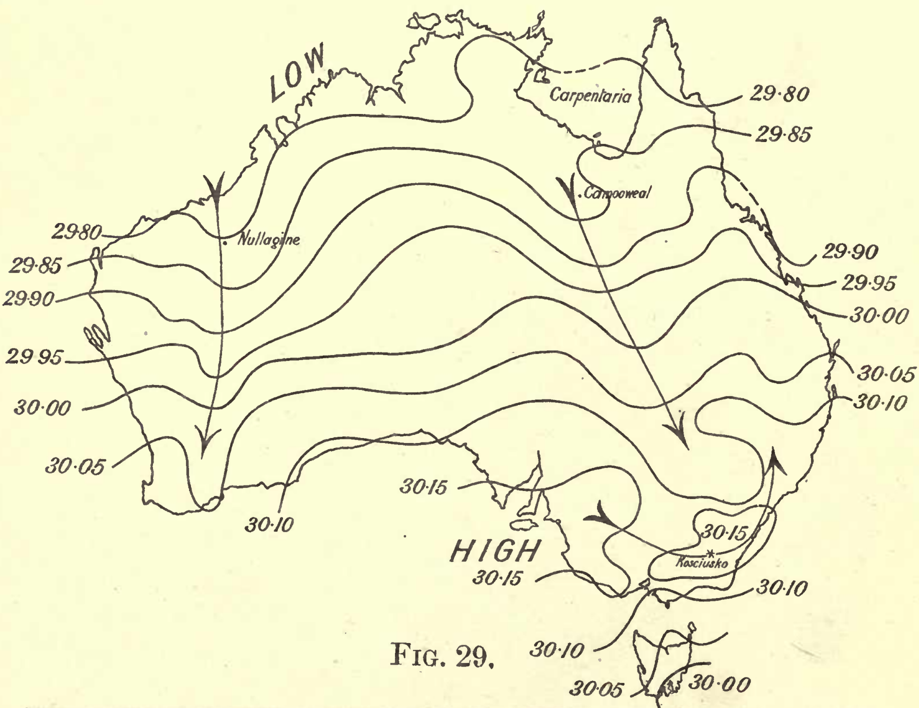



FIG. 29.

MEAN PRESSURE, JULY, 1910—A TYPE OF MIDWINTER DISTRIBUTION.

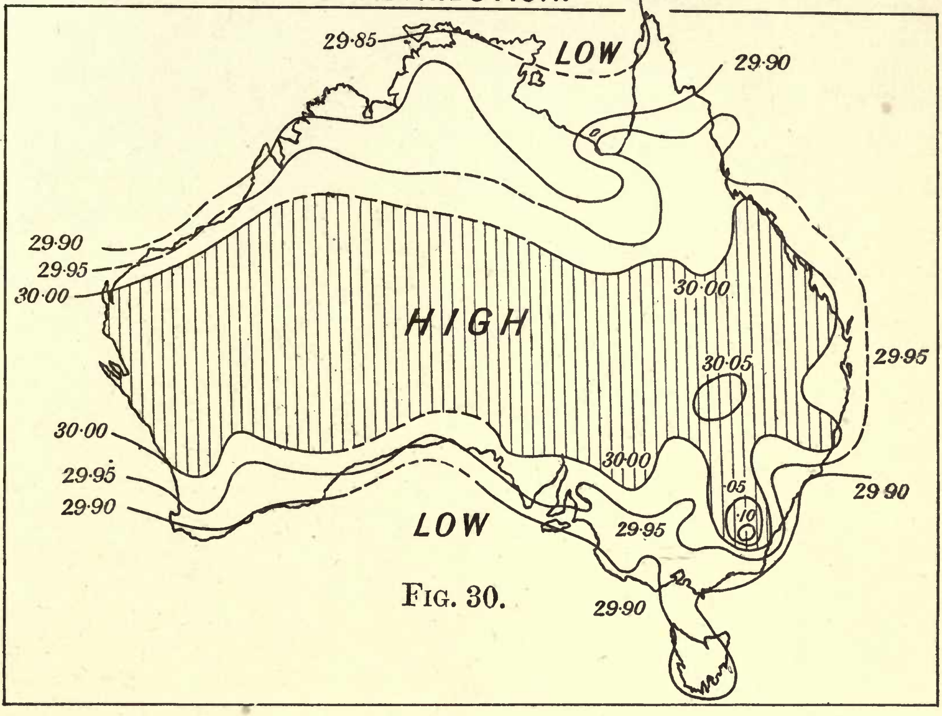



FIG. 30.

MEAN PRESSURE, DECEMBER, 1910—A TYPE OF MIDSUMMER DISTRIBUTION.

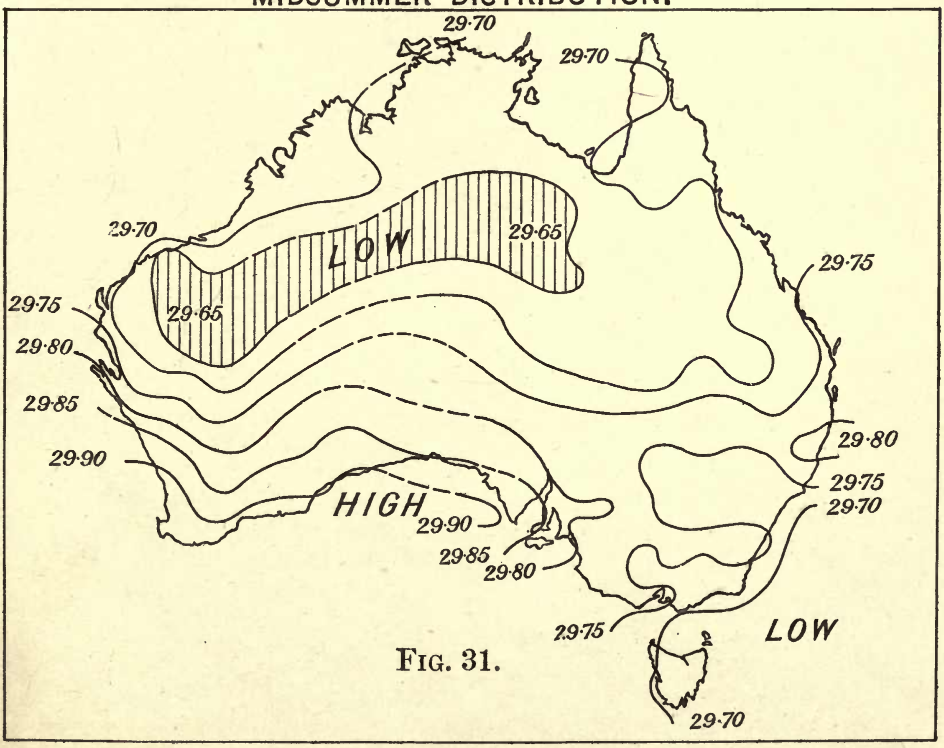



FIG. 31.

During winter, in May, June, July, and August, there is a well-marked area of high pressure centreing in the Western Plains of New South Wales, with the axis running approximately from Brisbane to Perth. The low-pressure isobars of 29·90 run parallel to this direction, through Port Darwin, in the north, and through Tasmania, in the south.

With the spring the monsoonal bulge from the north-west begins to move in and split the high pressure region into two—one area lying over Perth and the other over Brisbane.

In November and December the cyclonic area dominates north and west Australia, gradually concentrating over the intensely hot region around Pilbarra, Western Australia.

## Local Variation in Pressure.

Full data for the march of the isobars are avaliable for 1910 only, so that the following brief remarks refer to that year. They amplify the foregoing account, for very many more stations, giving very characteristic features to the isobars, are here used.

There is considerable resemblance between the direction of the isotherms and isobars, both being chiefly controlled by latitude. In *January*, 1910, there was a low-pressure area (29·6) situated just south of the Gulf of Carpentaria (within the Queensland *hot* loop), and another just off the Pearling Coast (29·6), The remaining isobars ran east and west with a definite tendency to follow the double curve of the south coast, and the maximum (30·0) appears in the extreme south of Tasmania.

In *February* the isobars were moving north as the continent cooled. The two northern loops were well marked over Nullagine (Western Australia), and Camooweal (Queensland) respectively, but the 30·0″ isobars formed a closed area over the Kosciusko cold loop. In *March* the isobar 29·7 followed the whole north coast, while 30·05 defined the south coast, bending north, however, over the Kosciusko Alpine area.

As the winter approached the high pressures tended to centre themselves around Kosciusko, the lower isobars forming around that elevated area. This was especially true in *May* and *June*. Then the high-pressure area spreads westward right across the continent, in July (midwinter) forming a broad belt between the tropic and the Bight with an average over 30·0 inches.

In *August*, as the centre of the continent warmed the high pressure retreated on Kosciusko from the west and north, and in *September* the low pressures (29·85, &c.) invaded Australia by the two hinterland loops of Pilbara and Carpentaria. In *October* the isobars had much the same distribution as in April, though the gradient was steeper in the south-east, over Tasmania.

In November the summer conditions began to recur, a low-pressure area (29·7) forming over the Pilbara area, and the Carpentaria loop running down into Queensland. The highest pressures were now on the New South Wales Coast, being pushed seawards as the highlands warmed under the southern sun. The monsoonal condition of Australia was very strikingly shown n the isobars of December, 1910, when the hot region (from the Pearling Coast to Camooweal, Queensland) was occupied by a belt of low pressure (29·65) around which isobars were arranged, the highest pressures being along the south-west coast from Leeuwin to Eucla.

## The Paths of the Highs and Lows.

Here also data are very incomplete except for 1910, but the main features can be deduced from a study of the tracks of the disturbances in that year.

Australian weather is controlled by three belts of atmospheric eddies. In the north moving (generally) from west to east, along the Tropic of Capricorn, is a procession of low pressure systems which are usually termed *monsoonal* lows. (The term "Tropical" might be less ambiguous, for in winter, at any rate, there is little akin to monsoonal conditions in Australian low-pressure areas.)

South of latitude 40° is another series of cyclonic eddies—probably secondaries strung along the great low-pressure belt of the Southern Ocean. These are called antarctic cyclones. Between the two lies the belt of anticyclones whose path, as we shall see, swings between latitude 30° and 42°, as the sun moves south and back again.

The general tracks of the disturbances are shown on the diagrams, Figs. 32—35 (for 1910), when three facts may be noted in their characteristics. The tropical belt is much more irregular, the paths being often recurved. This series is never well developed in winter, the months of April, May, June, July, and August being generally free from these disturbances.

*Statistics for* 1910.

| Month. | Anticyclones. | | Tropicals. | | Antarctics. | |
|---|---|---|---|---|---|---|
| | No. | Remarks. | No. | Remarks. | No. | Remarks. |
| January .. | 5 | .. .. | 5 | Knot south of Hall's Creek (2 on east coast) | 4 | |
| February | 4 | .. .. | 6 | Two tropical storms | 4 | |
| March .. | 6 | Of considerable average intensity | 6 | Two of storm intensity in Queensland | 4 | Of slight intensity |
| April .. | 6 | .. .. | 3 | Off north coast (none on land) | 8 | Only two noteworthy |
| May .. | 6 | Greatest intensity in east, and tendency to slow down there also | 1 | Over North Tasman Sea | 6 | Including two of north-west origin |
| June .. | 4 | (Two intense. 30·5) | 3 | Slight intensity | 6 | Half of cyclone energy |
| July .. | 7 | Moderate. Tended to have axis north and south | 2 | Very slight .. | 5 | Large, slow, stormy off south-west |
| August .. | 8 | More energy than July (7 normal track) | 1 | Low intensity .. | 7 | Less intensity; rather quicker |
| September | 5 | (Three, 30·5) ... | 6 | (Two Pilbara), (four Carpentaria) | 5 | (Two, vigorous) |
| October .. | 4 | (Two of considerable intensity) | 5 | Of slight intensity | 4 | Of marked energy |
| November | 6 | Generally slight, diverged to east | 4 | Very persistent. Much thunder | 7 | Quick movement |
| December | 8 | Of feeble intensity, except the last | 8 | Numerous, but sluggish | 8 | Numerous. More rapid |

## AVERAGE MONTHLY PATHS OF ANTICYCLONES, JANUARY-JUNE, 1910.

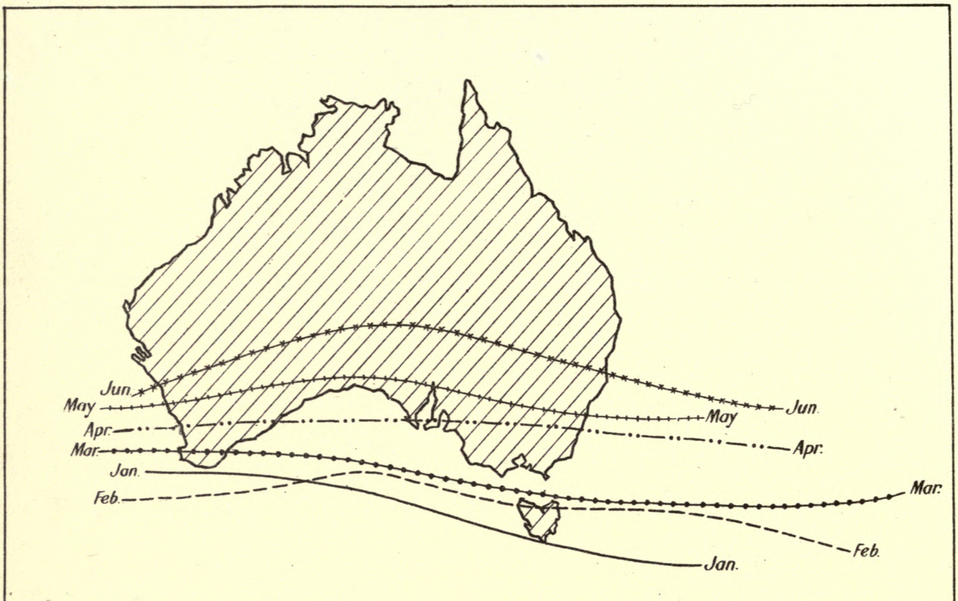



FIG. 32.

## JULY-DECEMBER, 1910

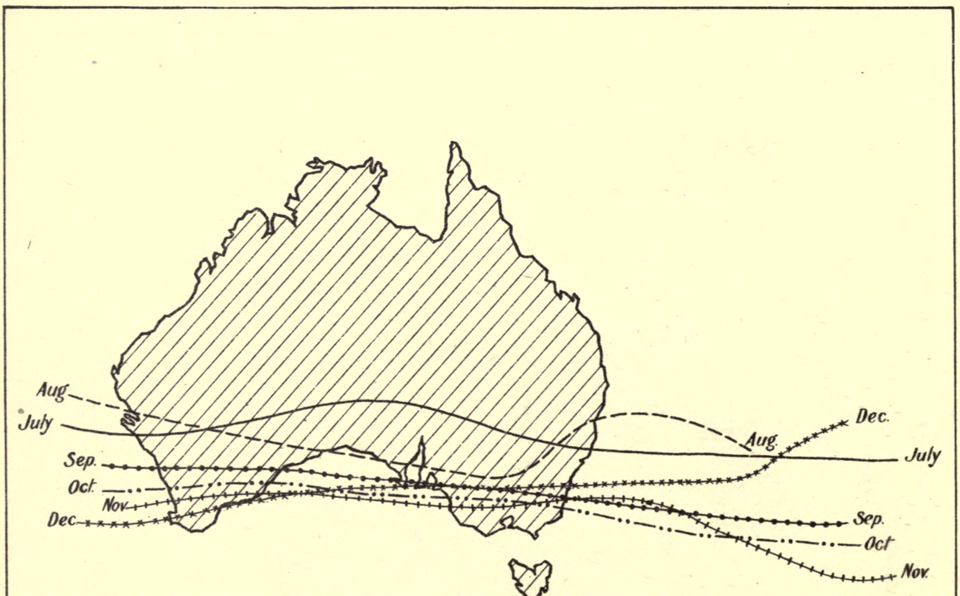



FIG. 33.

TRACKS OF LOWS, JANUARY-JUNE, 1910.

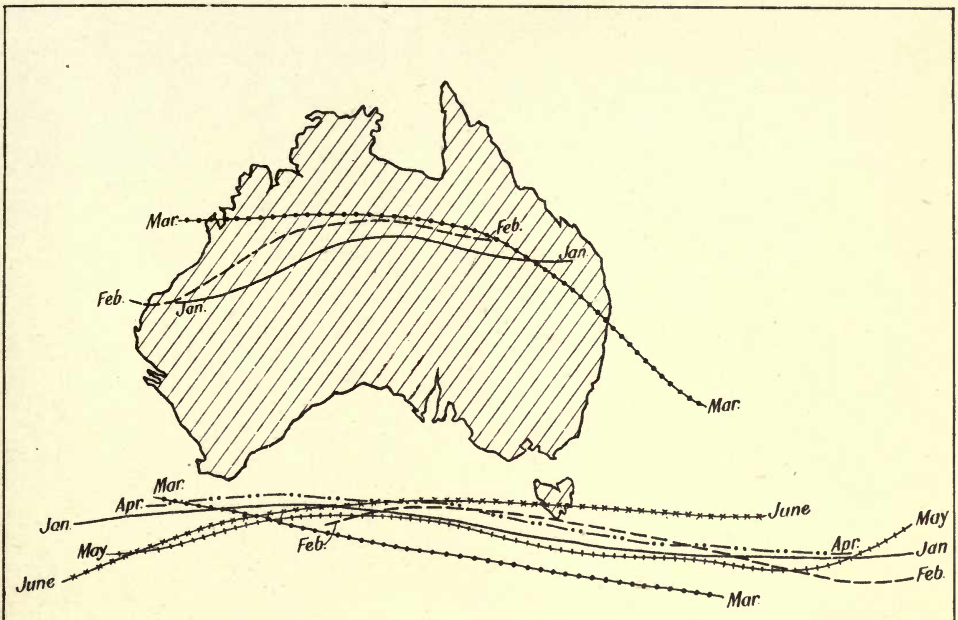



FIG. 34.

JULY-DECEMBER, 1910.

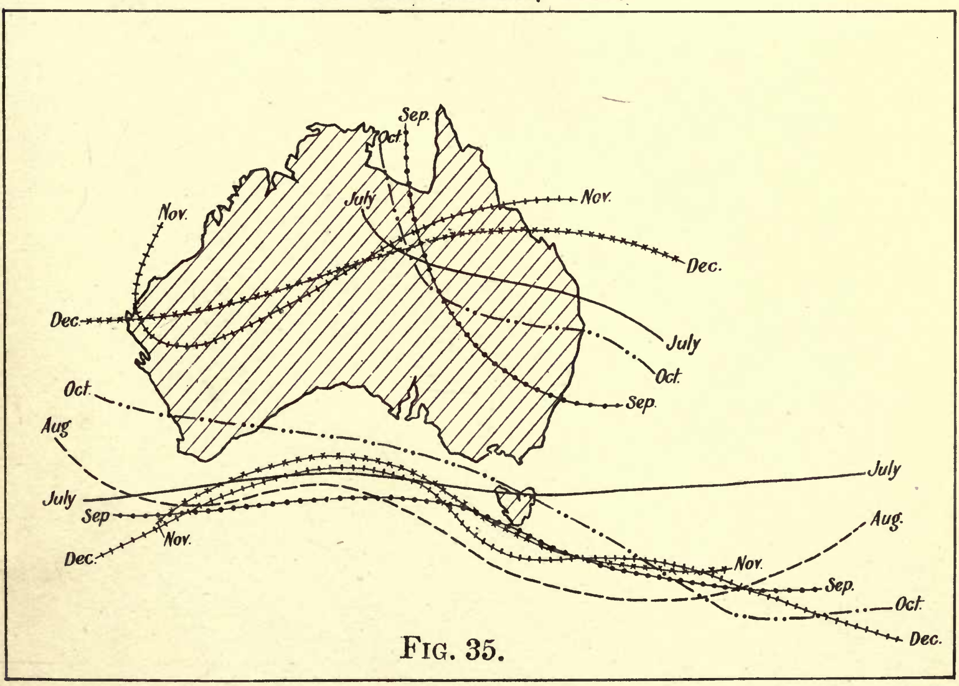



FIG. 35.

This table shows (as might be expected) that the anticyclones are most numerous in winter (July and August), and least numerous in midsummer. The tropical depressions are generally unimportant in winter (May, June, July, and August), and increase in number as the sun moves south to a position over the continent. The Antarctic disturbances are somewhat less in evidence at Midsummer. At this period the southern low-pressure belt has moved southward and its accompanying eddies (the Antarctic V's or ows) do not so often influence Australian weather.

### Speed of the Disturbances.

Sufficient data are not yet available for very accurate determinations of the speed of the disturbances. But one or two points of interest are obvious in any set of eddy charts.

The tropical lows show a marked tendency to "hang" about certain localities, such as the Pilbara heated area or the region south of the Gulf of Carpentaria. Examples of "hesitation" over Pilbara occur in the months of January, November, and December, and over Carpentaria in September, November, and December.

The velocity of the highs and lows across Southern Australia is also often very irregular. Their rate across the Australian Bight is greater than that they exhibit over South-western Australia, or over the Bass Straits area. Probably the frictional resistance is less over the water which in the Bight is thrust well northward across their path, than over the highlands in South-eastern Australia and Tasmania. But these velocities vary with the months. Thus in June, 1910, the lows off the Leeuwin averaged about 360 miles per day; over the Bight about 550 miles, and over Tasmania about 600 miles per day. In November of the same year the velocity of the lows showed an average of 830 miles across the Bight, and 500 to the south of Tasmania.

It must also be noted that it is difficult to fix the position and velocity of these southern eddies. Their centres lie over water areas often and the positions can only be deduced approximately from the form of their northern isobars.

## IV.—DOMINANT WINDS.

Some interesting particulars of the dominant coastal winds, which are more regular than those on land, have been collected from various publications, including the U.S.A. Pilot Charts.

The seas round Australia may be divided into the following regions :—

1. Northern or Tropical Region.
2. Queensland Coast.
3. New South Wales Coast.
4. South Australian Coast.
5. South-west Coast.
6. North-west Coast (Pearling Coast).

The dominant winds in the various months are given in the following table.

Where, as is often the case, winds from one particular octant are the most numerous, this direction only is given. Where, however, two *adjacent* octants are nearly equal, they are both given; and they are also grouped together under the intermediate direction. The figures refer to percentages of winds in the whole month.

DOMINANT WINDS ON AUSTRALIAN COASTS.

| — | 1. Northern Coast. | 2. Queensland Coast. | 3. New South Wales Coast. | 4. Southern Coast. | 5. South-west Coasts. | 6. North-west Coasts. |
|---|---|---|---|---|---|---|
| Cold Months. | | | | | | |
| April .. | E.S.E. = 65<br>E. = 33<br>S.E. = 32 | E.S.E. = 70<br>S.E. = 45<br>E. = 25 | Variable .. | W.S.W. = 42<br>W. = 22<br>S.W. = 20 | S.S.E. = 62<br>S.E. = 33<br>S. = 27 | S.E. = 33 and variable |
| May .. | E.S.E. = 61<br>E. = 33<br>S.E. = 28 | E.S.E. = 72<br>S.E. = 47<br>E. = 25 | Variable .. | Variable and W. | Variable and S.E. | S.E. = 48 and variable |
| June .. | E.S.E. = 82<br>S.E. = 42<br>E. = 40 | E.S.E. = 55<br>S.E. = 33<br>E. = 22 | S.W. and variable | Variable ..<br>W. = 24<br>N.W. = 20 | Variable .. | S.E. = 45 |
| July .. | E.S.E. = 81<br>S.E. = 43<br>E. = 38 | E.S.E. = 59<br>S.E. = 32<br>E. = 27 | Variable .. | Variable .. | S.W. and variable | S.E. = 35 |
| August .. | S.E. = 42 | E.S.E. = 68<br>S.E. = 35<br>E. = 33 | S.W. and variable | Variable and W. | Variable .. | S. to E. and variable |
| September | S.E. = 37 | S.E. = 68<br>E. = 38<br>S.E. = 30 | Variable .. | Variable .. | Variable, S.E. through W. to N.W. | S.S.E. = 67<br>S. = 35<br>S.E. = 32 |
| Warm Months. | | | | | | |
| October .. | S.E. = 34 | E.S.E. = 65<br>E. = 35<br>S.E. = 30 | Variable .. | W. = 21 .. | S.S.W. = 55<br>S. = 33<br>S.W. = 22 | S.E. = 35 |
| November.. | S.E. = 40 | E.S.E. = 62<br>E. = 33<br>S.E. = 29 | Variable .. | W. and variable | S. = 33 .. | S.E. = 38 |
| December | W. and variable | E.S.E. = 67<br>E. = 36<br>S.E. = 31 | N.E. and variable | S.W. and variable | S. = 35 .. | S.W. = 25 |
| January .. | Variable .. | E.S.E. = 76<br>E. = 46<br>S.E. = 30 | Variable .. | W.S.W. = 39<br>S.W. = 21<br>W. = 18 | S.S.E. = 77<br>S. = 43<br>S.E. = 34 | S.W. = 30 |
| February .. | W. and variable | E.S.E. = 66<br>E. = 36<br>S.E. = 30 | N.E. = 20 variable | S. to W. .. | S. = 28 .. | S.W. = 31 |
| March .. | E.S.E. = 62<br>E. = 33<br>S.E. = 29 | E.S.E. = 75<br>S.E. = 46<br>E. = 29 | Variable .. | W.S.W. = 43<br>W. = 23<br>S.W. = 20 | S.S.E. = 74<br>S. = 41<br>S.E. = 33 | Variable |

*Note.*—Figures represent percentages of all winds of month.

In this table the months are grouped as cold and warm respectively. This brings out the paramount importance of the sun's annual swing in connexion with the change in direction of the prevailing winds. Of the six wind regions concerned, three (III, IV, and V) may be classed as *variable* and three as *steady* (I, II, and VI).

1. *The Northern Coast* (from Cambridge Gulf to Cape York) may be discussed first. It is seen that the dominant winds throughout the colder months (and indeed, except in December, January, and February) are confined to the south-east quarter. During this period the monsoonal effect of the Asiatic Massif is controlling Northern Australia. In Midsummer

(January) the centre of Australia is heated strongly and the winds on the north coast become much less constant, those from the west predominating. As the sun moves north again the wind changes to an easterly, and in June the south-easter is again dominant. It should be remembered that calms are very prevalent in this region.

2. *The Queensland Coast* (from Cape York to Brisbane) exhibits somewhat similar changes, but here are the most constant winds in Australia, for even in summer the wind merely veers from south-east to east. In January 46 per cent. of the winds are from the east and 30 per cent. from the south-east. In May 47 per cent. are from the south-east and 25 per cent. from the east.

3. *The New South Wales Coast.*—Here, as might be expected, the winds are very variable, for the region of the high pressure eddies is reached. Still there is some differentiation apparent. During midwinter (June, July, and August) there is, perhaps, a preponderance of south-west winds, due to the cold elevated area around Mt. Kosciusko. In midsummer (December, January, February) there is a similar local "monsoon" effect, giving rise to a strengthening of the north-east components.

4. *The Southern Coasts*, from Cape Howe to Cape Leeuwin, are on the border line between the high pressure belt and the region of prevailing westerlies. The centres of the Antarctic depressions—moving from west to east—lie considerably south of our coasts; and hence these coasts are controlled by the north component (upper limb) of these depressions or eddies. Here the winds are westerly, and this fact probably accounts for the high aggregate of westerlies recorded in this region, although it is constantly traversed by circulating systems or cyclones.

5. *The South-west Coast*, from Cape Leeuwin to North-west Cape.—Here the winds throughout the year blow chiefly from south and west. A south-east component is more apparent during midsummer and autumn. The westerly component enters this region in winter, as the sun moves north and the southern "prevailing westerlies" swing northwards in unison and affect Western Australia.

The two varying factors of south-east and south-west respectively are in fact but the result of the swing of the *trade wind* south in summer and of the *westerlies* north in winter.

6. *The North-west Coast*, from North-west Cape to Cambridge Gulf.—This region agrees fairly closely with the northern region. It is dominated by the south-east trade for eight months, but during midsummer the almost permanent "low" covering the hot Pilbara region in Western Australia gives rise to a "monsoon" and the coastal winds swing round from south-east to south-west. The south-east wind is, however, not so constant as that off the Queensland Coast, and in autumn (March, &c.) the winds are very variable. In the north calms are common, and except for the "willy-willies" storms are rare.

## The South-East Trade Winds.

The whole coast of Australia from Perth northward and east to Brisbane is at times influenced by the South-east Trade, so that a *résumé* of the movements of this important air current will be of interest.

In April the coastal winds are practically all S.S.E. or E.S.E. over this immense stretch of coastline, the only marked deviation being the occurrence of some S.W. winds (20 per cent. only) off Kimberley. In May, the belt has moved north to Geraldton, but is otherwise unchanged. In June it does not extend south of North-west Cape, but is stronger off Kimberley. In July, August, September, and October, it is practically continuous from North-west Cape to Rockhampton.

In November, as the sun moves south, the belt extends down to Geraldton. In December the Australian monsoon causes a break from North-west Cape to the Gulf of Carpentaria (dominated by west winds), and the South-east Trade forms a fringe on each side. This hiatus lasts through January and February, and in the last month the South-east Trade is hardly distinguishable on the West Coast. In March, the intervening region of S.W. winds is confined to the north-west coast, and the trades are again in evidence south to Perth.

In April the whole north-west, north, and north-east coasts are controlled by the trade winds.

### Land and Sea Breezes.

Since so large a portion of the population of Australia lives on the seaboard, these winds are of great importance. Data are lacking except at the capitals, but type examples from Perth and Adelaide will serve to indicate the effect of the diurnal change.

In Fig. 36 the winds throughout the day are averaged for each month for Perth. (Data for all years to the end of 1911.)

In the first column the average for the month is given. (Here we tend to get the diurnal extremes neutralizing each other so that the normal wind of the region is shown.)

*Regional Winds at Perth—*

| | | |
|---|---|---|
| South wind .. | In October, November, December, and January | Summer |
| South-east .. | In February, March, and April .. | Autumn |
| North-east .. | In May, June, and July .. .. | Winter |
| South-west .. | In August, September .. .. | Spring |

In this locality the invigorating sea-breeze—called the "Doctor"—blows from the W.S.W. during the afternoon, while a land wind (E.N.E.) sets in when the land has cooled below sea temperatures in the early morning.

The sea-breeze is most active when the land is *much* warmer than the sea, *i.e.*, in the summer. The land breeze is most active for similar reasons in winter.

Thus we see that in winter the two factors (the normal north-east wind and the land breeze) are assisting each other. Hence the constant N.E. winds every morning during this season. For the rest of the year the morning winds are from the south-east, the resultant of the southerly regional wind and the N.E. land breeze.

The sea breeze absolutely controls the wind direction at Perth in the afternoon, even in winter, and in the summer not much deflection of the normal south wind is necessary to bring it into line.

# LAND & SEA BREEZES AT PERTH.

LAND YEARS TO END OF 1911 SEA

| | Month | Average | Midnight | 3 a.m. | 6 a.m | 9 a.m. | Noon | 3 p.m. | 6 p.m. | 9 p.m. |
|---|---|---|---|---|---|---|---|---|---|---|
| S. Winds | JAN. | S. | S. | E.S.E. | E.S.E. | E.S.E. | S. | S.S.W. | S.S.W. | S. |
| South East Winds | FEB. | S.S.E. | S.S.E. | S.E. | E.S.E. | E.S.E. | S.S.E. | S.S.W. | S.S.W. | S. |
| | MAR. | S.S.E. | S.S.E. | S.E. | E.S.E. | E. | S.S.E. | S.S.W. | S.S.W. | S. |
| | APR. | S.E. | S.E | E.S.E. | E. | E. | S.E. | S.S.W | S.S.W. | S |
| North East Winds | MAY | E.N.E | E. | E.N.E. | N.E. | N.E. | N.N.E. | W.S.W. | S.W. | S.E. |
| | JUN. | N.N.E. | N.E. | N.N.E. | N.N.E. | N.N.E. | N. | W.N.W. | W.S.W. | E. |
| | JUL. | N.N.E. | N.E. | N.N.E. | N.N.E. | N.N.E. | N.N.E. | W. | W.S.W. | S.S.E. |
| S. W. Winds | AUG. | W.S.W. | S.E. | S.S.E. | N.E. | N.E. | N.W. | W.S.W. | S.W. | S.S.W. |
| | SEP. | S.W. | S. | S.S.E. | E.N.E. | N.E. | S.W. | W.S.W. | S.W. | S.S.W. |
| South Winds | OCT. | S.S.W. | S. | S.S.E. | E.S.E. | S.E. | S.W. | S.W. | S.W. | S.S.W. |
| | NOV. | S. | S. | S.S.E. | S.E. | S.E. | S.S.W. | S.W. | S.S.W. | S.S.W. |
| | DEC. | S. | S. | S.S.E. | S.E. | S.E. | S.S.W. | S.W. | S.S.W. | S. |

FIG. 36.

# LAND & SEA BREEZES AT ADELAIDE.

LAND ← 1907 SEA →

| | Month | Average | Midnight | 3 a.m. | 6 a.m. | 9 a.m. | Noon | 3 p.m. | 6 p.m. | 9 p.m. |
|---|---|---|---|---|---|---|---|---|---|---|
| *Summer:—Modified South Winds* | JAN. | S. | S.S.E. | S.S.E. | S.S.E. | S.W. | S.W. | S.S.W. | S. | S.S.E. |
| | FEB. | S.S.E. | S.E. | E.S.E. | E.S.E. | E. | W.S.W. | S.W. by S. | S. | S.E. |
| | MAR. | S.S.E. | S.S.E. | S.S.E. | S.E. | S.E. | S.S.W. | S.S.W. | S. | S.S.E. |
| | APR. | S.S.W. | S.W. | S.S.E. | S.S.E. | E.N.E. | W. | W.S.W. | S.W. | S.W. |
| *Winter:—Modified North Winds* | MAY | N. | E. | N.E. | E. by N. | N.E. by N. | N.N.W. | W. | W. | E.N.E. |
| | JUN. | N.E. | E.N.E. | E. | E.N.E. | N.E. by E. | N.N.E. | N. by W. | E.N.E. | E.N.E. |
| | JUL. | N.N.W. | N. | N. | N. by E. | N.N.E. | N.W. by N. | N.W. | N.W. | N. by W. |
| | AUG. | N.W. | N.N.W. | N. | N. | N. by W. | N.N.W. | W.N.W. | W.N.W. | N.W. by |
| | SEP. | N.N.W. | E. | E.N.E. | N.N.E. | N. | W.N.W. | W. by N. | W. by S. | W. |
| *Spring:—Modified S.W. Winds* | OCT. | W.S.W. | S. | S.W. | S. by W. | N.W. | W. by N. | W. by S. | S.W. | S.W. |
| | NOV. | S.W. | S.S.E. | S.E. | S.E. | N.N.W. | W. | S.W. by W. | S.W. | S. by E. |
| | DEC. | S.S.W. | S.S.E. | S.S.E. | S.S.E. | S. | W.S.W. | S.W. | S.S.W. | S. by E. |

FIG. 37.

In conclusion it may be noted that there is each day a noteworthy change in wind direction near noon. During the first half of the year (February–July) this occurs just *after* noon; in the latter half of the year (August–January) just *before* noon.

In Adelaide, much the same phenomena can be noticed. (Fig. 37.)

The normal winds of this region (deduced from the average throughout the month) are—

South winds .. In summer (January, February, March, April).
North winds .. In winter (May, June, July, August, September).
South-west winds In Spring (October, November, December).

Here the coastline has much the same direction as at Perth. So that the land breeze is E.N.E. and the sea breeze W.S.W. as before.

It will be noticed that the land wind is very strong in the months of May and June. It also deflects the normal wind appreciably, but not very greatly in other months. The sea breeze is not strong in winter, but all the rest of the year is very important in the afternoon, exercising a strong deflection in January, February, and March.

## V.—RAINFALL.

### Distribution of Rainfall.

Australia and Tasmania cover 2,974,581 square miles. Of this total area, 1,045,073 square miles have less than 10 inches per annum on the average; 651,961 square miles have from 10 to 15 inches; 416,135 from 15 to 20 inches; 502,929 square miles from 20 to 30 inches; 198,608 square miles from 30 to 40 inches; and 159,875 square miles have an annual average rainfall of over 40 inches.

### Chief Rain-storm Types and Seasons of Rain.

The rains of Australia fall mainly in connexion with two storm types, viz., tropical depressions and southern depressions, the latter locally known as Antarctic depressions.

The former rain-bearing factor operates over two-thirds of the continent, roughly, over that portion of Australia lying to the north of a line extending approximately from Cossack on the North-west Coast to Sydney on the south-east coast, the rainy season being from December to March inclusive, and the wettest month, January.

The remaining third of Australia's area receives its rain principally through the southern depressions which operate during the autumn, winter, and spring months, with the heaviest monthly totals in June.

Convectional rains may occur at any season in the interior, and cyclonic rains visit the east coast in northern parts during the summer months, and in the winter and spring months on the Southern or New South Wales coastal regions.

A considerable amount of anti-cyclonic rain falls over the eastern coastal districts of the continent at any time of the year, when the recurring high-pressures pass in high latitudes and are actually centred to the west of Tasmania.

### Rainfall—Monthly and Seasonal Distribution.

In a map showing the annual rainfall of the continent the isohyets form approximately concentric ovals around the arid centre of the continent. This arrangement does not, however, mean that the coastal regions are always

wet; although unfortunately it is true that the interior is nearly always dry. As we shall see, in each month the region with over 1 inch of rainfall forms a somewhat "crescent" shaped area, whose concavity lies toward the centre. These "crescents" slowly swing round from north, through east to south, and then back again during the year.

Let us now consider the months in some detail.

In *January* the sun's heat effect is greatest, and the monsoon is at its height. The cold Tibetan Plateau and warm centre of Australia act in unison to produce many on-shore northerly winds in Northern Australia, and hence an average of ½ inch of rain falls each day at Port Darwin—gradually decreasing towards the south. Alice Springs (in the centre) gets about 1 inch in the month, while south and south-west Australia receive practically no rain.

In *February* the rain belt is less intense at Port Darwin, the monthly fall being 10 inches instead of 15 inches; but otherwise the distribution over the continent is much the same.

In *March* the summer rains have retreated still further north, and the southern limb of the "crescent" is beginning to cover the south-west coast. (The S.E. Trades have given the Queensland coast near Cairns over 20 inches during each of the three months considered.)

In *April* the winter rains are beginning to be felt along the whole south coast, though only to the extent of an inch or so during the month.

In *May* the southern type of rainfall is in full swing and no rain falls in the north. The "crescent" has now tilted round to face the south and its two limbs cover the east and west coastal areas.

In *June*, *July*, and *August*, similar conditions obtain; the rain belt (over 1 inch) having still the shape of a crescent, and covering the coast from North-west Cape around the south and up the east coast to Cooktown.

*September* is, perhaps, the driest month in the year; if we consider Australia as a whole. Only the extreme south-west corner of Tasmania and the Cordillera region in the south-east have a rainfall of over 2 inches. The southern rains are now moving south as the sun retraces his path from his northern limit.

In *October* there can hardly be said to be a rain *belt*, for the rain region is divided into three isolated areas. The northward bulge of the Southern Ocean in the Bight has severed the winter rain area in two, while in Northern Territory the summer rains are again creeping southward and are giving that settlement over 2 inches. For six months (since April) the north-west coast and York Peninsula have had practically no rain.

In *November* the winter rains are over. The "crescent" faces toward the N.E. again, and the monsoonal rains are dominating the north of the continent. In *December* the summer rain has reached Alice Springs in the centre of the continent and over an inch has fallen in that region.

Many interesting points in connexion with the origin of the rainfall are brought out by these monthly charts. They will be discussed briefly in the next chapter. It will have been noticed that the "crescents" face north in summer (Figs. 50, 39, 40), east in autumn (Figs. 41, 42, 43), and south in winter (Figs. 44, 45, 46), but never occupy the west coast; while the centre also is never covered by the crescentic monthly rain areas.

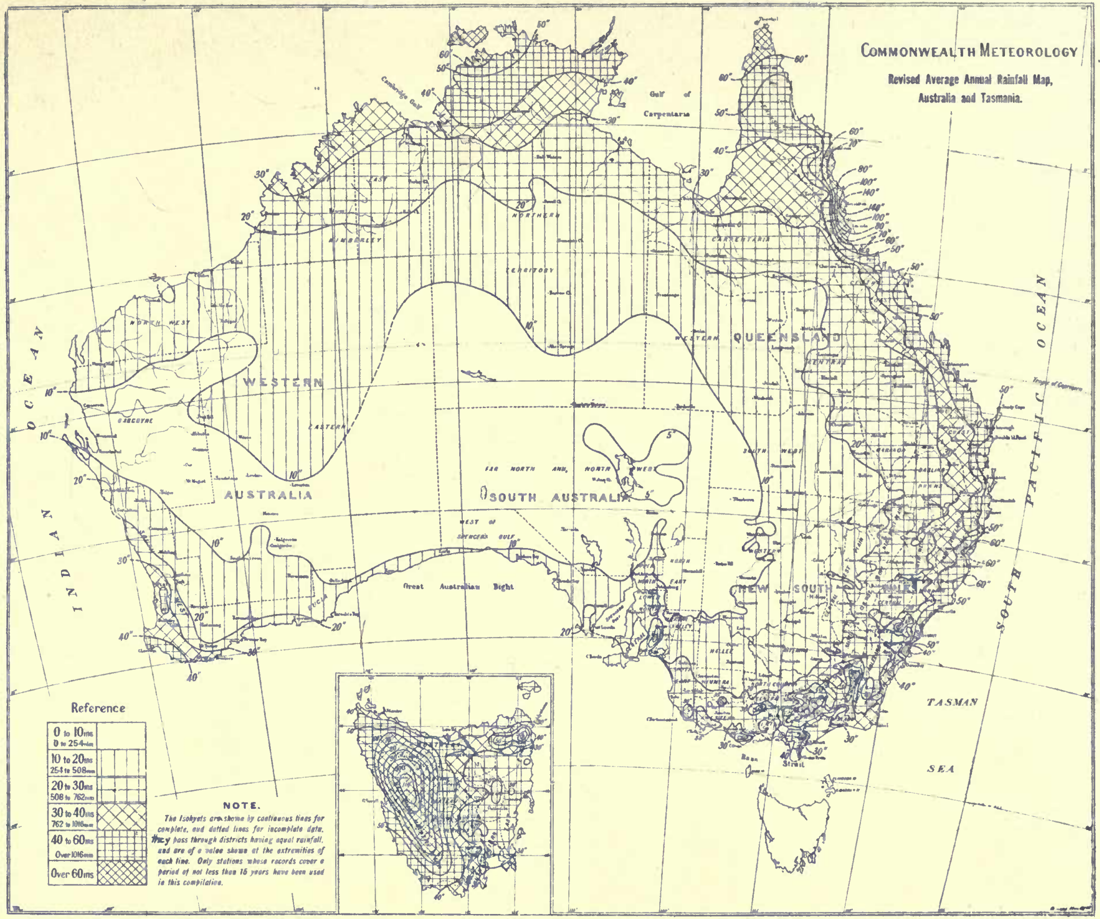

COMMONWEALTH METEOROLOGY
Revised Average Annual Rainfall Map, Australia and Tasmania.
Reference
0 to 10ins 0 to 254mm
10 to 20ins 254 to 508mm
20 to 30ins 508 to 762mm
30 to 40ins 762 to 1016mm
40 to 60ins Over 1016mm
Over 60ins
NOTE.
The Isohyets are shown by continuous lines for complete, and dotted lines for incomplete data. They pass through districts having equal rainfall, and are of a value shown at the extremities of each line. Only stations whose records cover a period of not less than 15 years have been used in this compilation.
INDIAN OCEAN
SOUTH PACIFIC OCEAN
TASMAN SEA
Gulf of Carpentaria
Great Australian Bight
WESTERN AUSTRALIA
SOUTH AUSTRALIA
QUEENSLAND
NEW SOUTH WALES
Bass Strait

FIG. 38.

# MEAN MONTHLY RAINFALL.

Fig. 39.

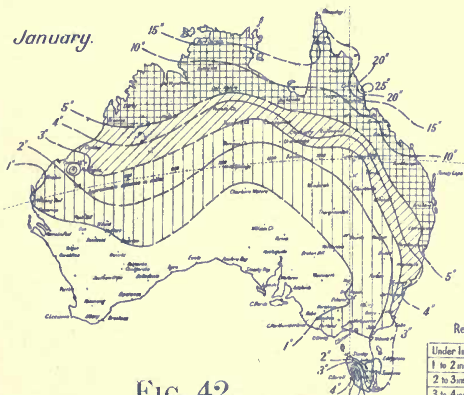



Fig. 40.

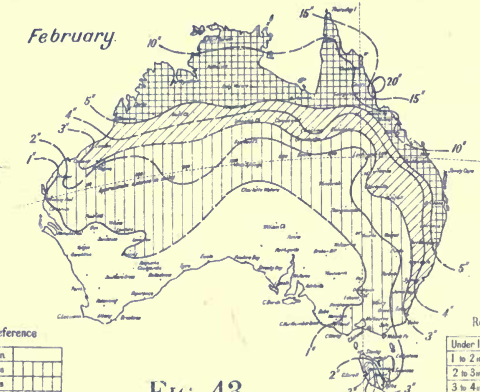
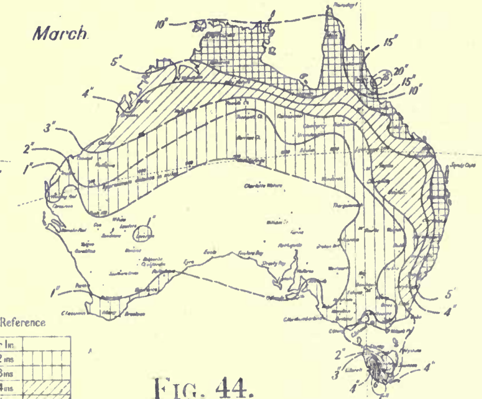



Fig. 41.




Reference

| | |
|---|---|
| Under In. | |
| 1 to 2 ins | |
| 2 to 3 ins | |
| 3 to 4 ins | |
| 4 to 5 ins | |
| Over 5 ins | |

Fig. 42.

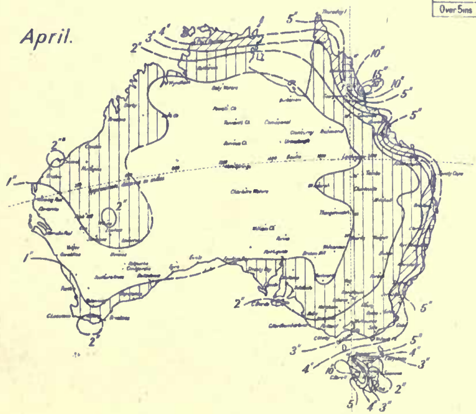
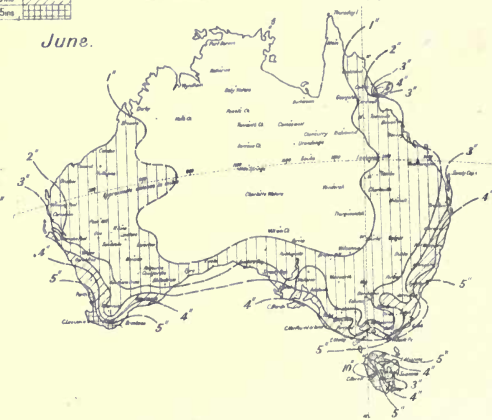



Fig. 43.


Fig. 44.




Reference

| | |
|---|---|
| Under In. | |
| 1 to 2 ins | |
| 2 to 3 ins | |
| 3 to 4 ins | |
| 4 to 5 ins | |
| Over 5 ins | |

# MEAN MONTHLY RAINFALL.

FIG. 45.

*July.*

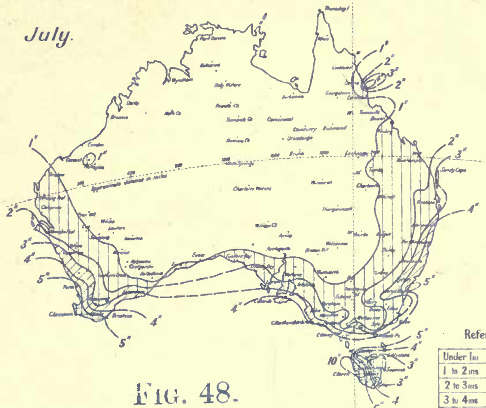


FIG. 46.

*August.*

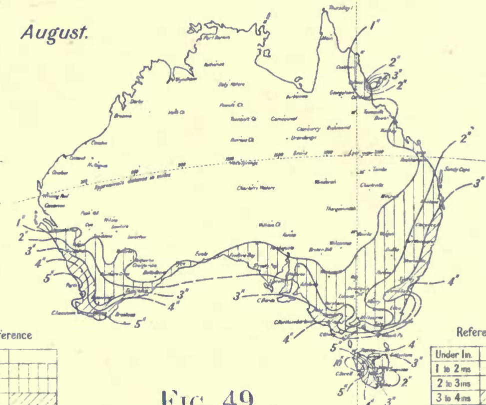
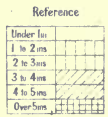


FIG. 47.

*September.*



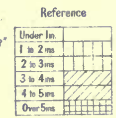




FIG. 48.

*October.*

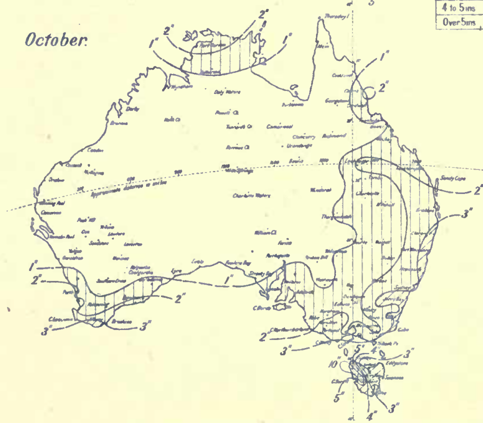


FIG. 49.

*November.*

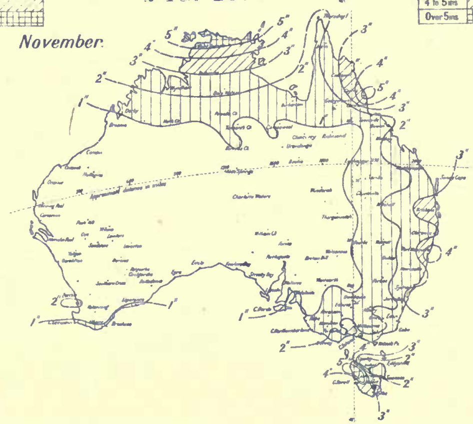
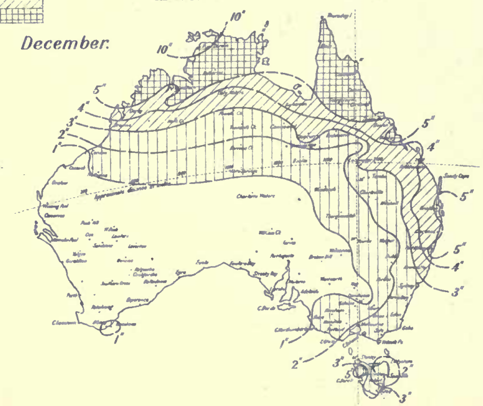
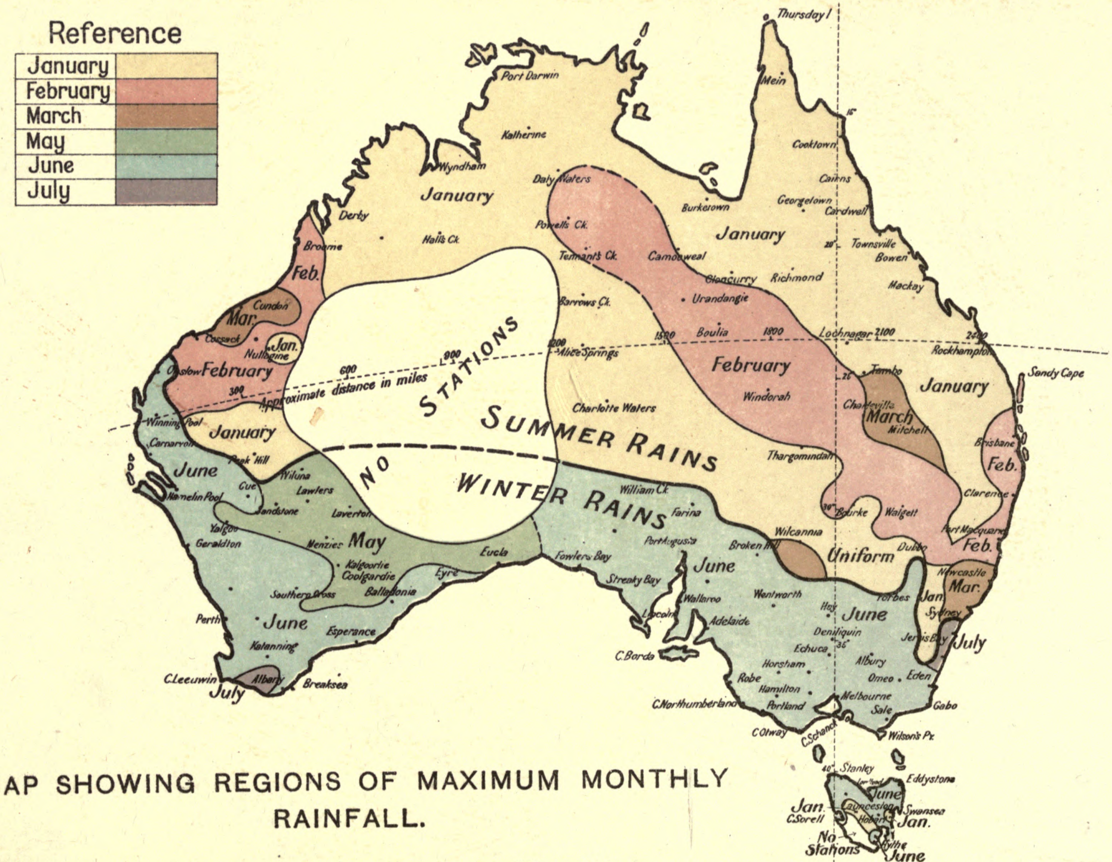


FIG. 50.

*December.*






MAP SHOWING REGIONS OF MAXIMUM MONTHLY RAINFALL.

FIG. 51.

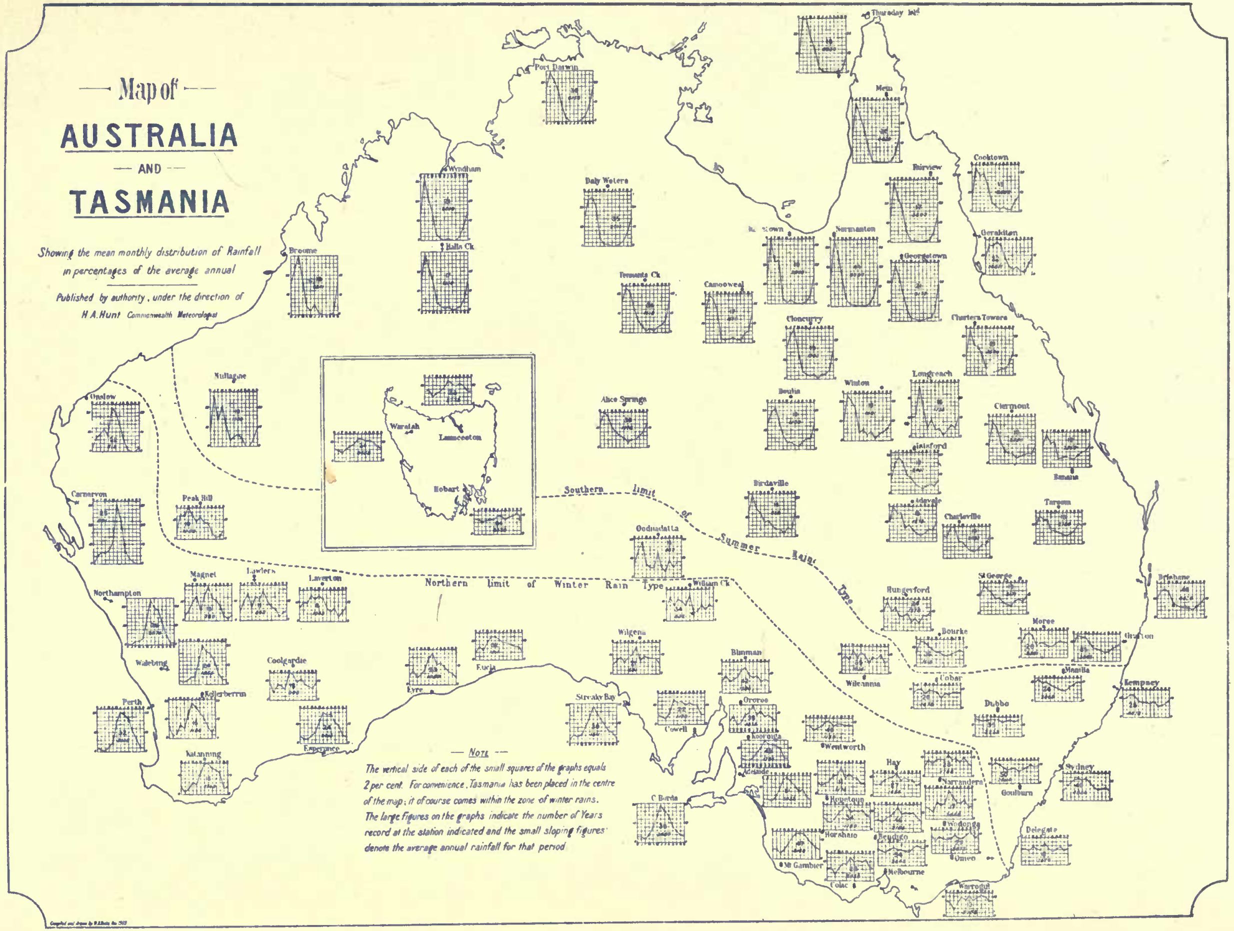

Map of
AUSTRALIA
AND
TASMANIA
Showing the mean monthly distribution of Rainfall in percentages of the average annual
Published by authority, under the direction of H. A. Hunt Commonwealth Meteorologist
Southern limit of Summer Rain Type
Northern limit of Winter Rain Type
NOTE
The vertical side of each of the small squares of the graphs equals 2 per cent. For convenience, Tasmania has been placed in the centre of the map; it of course comes within the zone of winter rains.
The large figures on the graphs indicate the number of Years record at the station indicated and the small sloping figures denote the average annual rainfall for that period
Thursday Isd
Port Darwin
Wyndham
Halls Ck
Broome
Daly Waters
Normanton
Georgetown
Cooktown
Geraldton
Charters Towers
Cloncurry
Camooweal
Longreach
Winton
Boulia
Clermont
Banana
Alice Springs
Birdsville
Charleville
Tarqom
Oodnadatta
William Ck
Hungerford
St George
Moree
Brisbane
Bourke
Cobar
Wilcannia
Dubbo
Kempsey
Wentworth
Hay
Goulburn
Sydney
Narrandera
Bendigo
Omeo
Delegate
Melbourne
Horsham
Colac
Warragul
Mt Gambier
Adelaide
C Borda
Cowell
Streaky Bay
Wilgena
Blinman
Eucla
Eyre
Coolgardie
Esperance
Katanning
Perth
Kellerberrin
Walebing
Northampton
Magnet
Lawlers
Laverton
Carnarvon
Peak Hill
Onslow
Nullagine
Waratah
Launceston
Hobart

FIG. 52.

## VI.—HUMIDITY AND WET BULB TEMPERATURES.

Except for the head stations, these records are not very numerous or reliable. An attempt has been made to collect the data for 1910; and the wet and dry bulb isotherms for midsummer (January) and midwinter (July) are shown in Figs. 53 and 54.

From the January isotherms, it will be noticed that in the hottest regions of Australia, the Pilbara Gold-fields, Western Australia, the humidity is by no means high.

The following table gives humidity figures for the hottest and coldest months at various stations. A comparison is interesting.

| Station. | Relative Humidities. January. | Relative Humidities. July. |
|---|---|---|
| Nullagine | 35 % | 50 % |
| Broome | 71 ,, | 49 ,, |
| Cossack | 55 ,, | 59 ,, |
| Peak Hill | 29 ,, | 60 ,, |
| Coolgardie | 43 ,, | 72 ,, |
| Perth | 52 ,, | 78 ,, |
| Adelaide | 36 ,, | 76 ,, |
| Melbourne | 64 ,, | 80 ,, |
| Sydney | 70 ,, | 77 ,, |
| Brisbane | 66 ,, | 73 ,, |

From this it will be noted that the humidity reaches only 29 per cent. at Peak Hill and 35 per cent. in midsummer at Nullagine.

At Broome, further north and on the coast, the humidity is 71 per cent., and it increases to 78 per cent. at Port Darwin in January. All down the east coast the heavy rainfall leads to much greater humidity than on the west coast. But, as the rainfall decreases rapidly towards the interior, the region with humidities over 70 per cent. in midsummer is very narrow.

In the chart showing the wet and dry bulb isotherms for July (see Fig. 54) the north of Australia at this time is experiencing the dry season, so that high humidities can only occur in the south. Since the average dry bulb temperature in the southern moiety is only about 50° F., none of these humidities—though well above 80 per cent. in places—have any deleterious effect on health.

Humidity data for the six capital cities are given in the following paragraph, together with graph relating to the monthly humidity and temperature :—

(1) *Perth.*—At Perth the mean annual humidity at 9 a.m. is 62 ; the greatest monthly mean is 83, and is in June ; and the lowest, 42, in January.

(2) *Adelaide.*—At Adelaide the mean annual humidity at 9 a.m. is only 56 ; the mean monthly humidity has been as low as 33 in January and December, and as high as 94 in June.

(3) *Brisbane.*—In Brisbane the mean annual humidity at 9 a.m. is 68 ; the lowest monthly mean recorded is 47, and is in September ; and the highest, 85, in the months of March and May.

(4) *Sydney.*—In Sydney the mean annual humidity at 9 a.m. is 73, the greatest monthly average, which occurred in May, 1891, was 90 ; whilst the lowest monthly mean, 52, occurred in the month of December, 1911.

## CHARTS SHOWING HUMIDITY, ALSO WET AND DRY BULB ISOTHERMS.

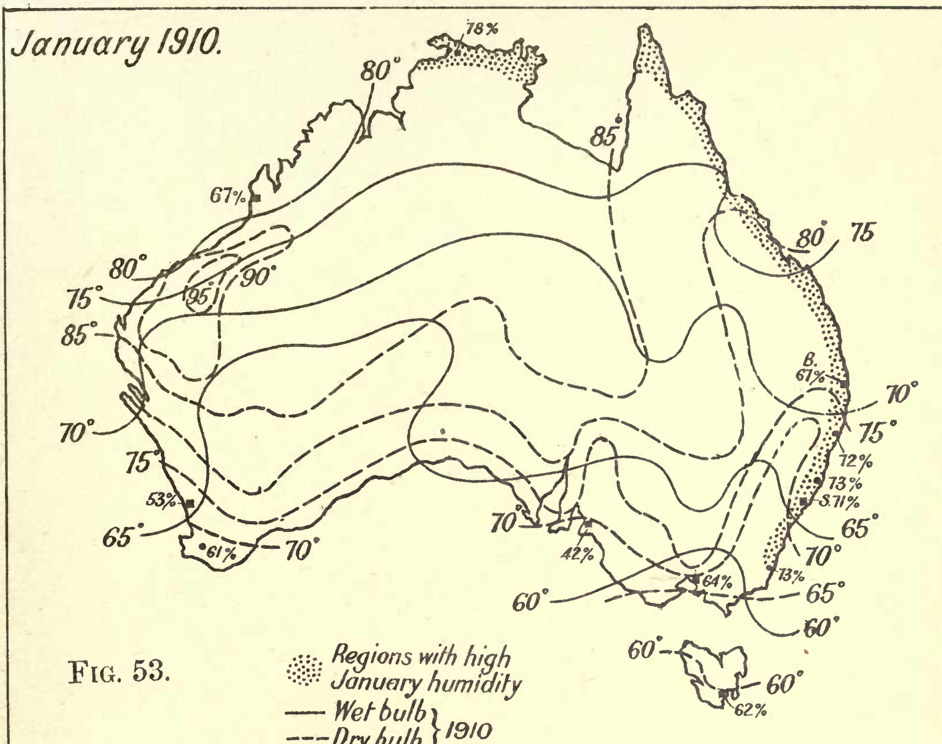



Fig. 53.

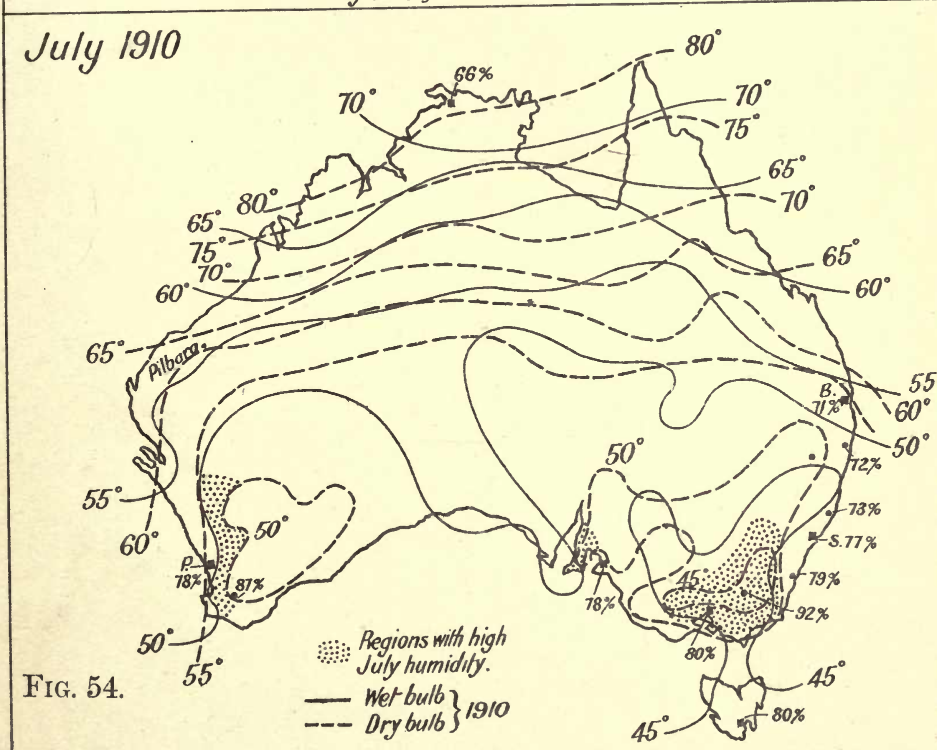
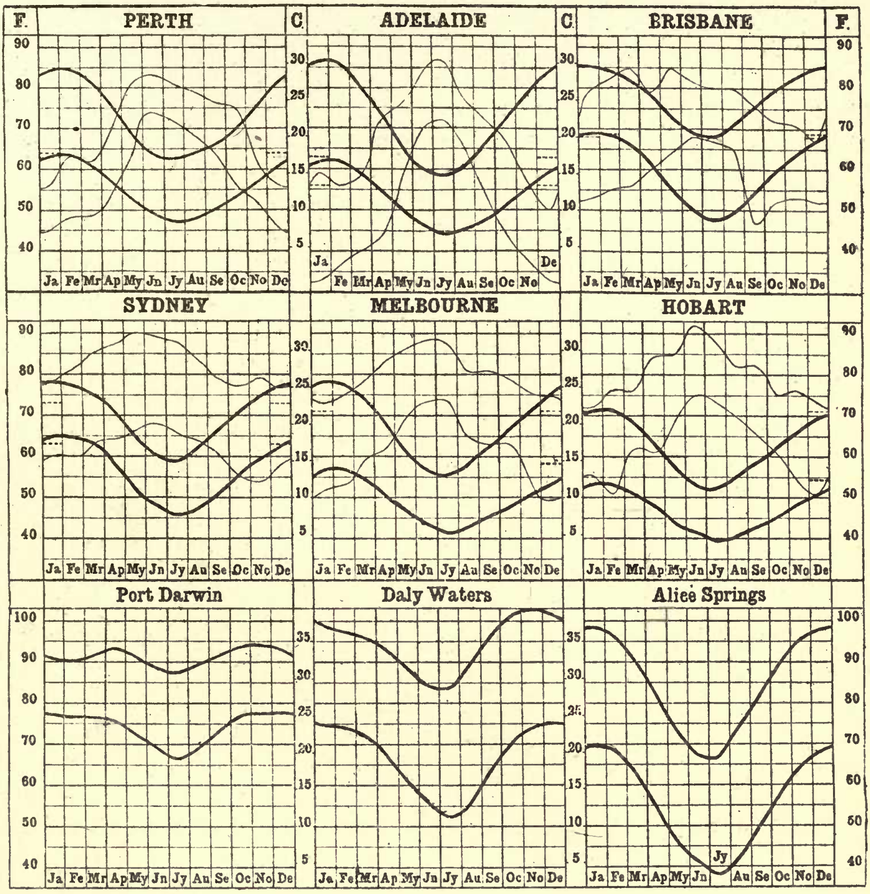



Fig. 54.

GRAPHS SHEWING ANNUAL FLUCTUATIONS OF MEAN MAXIMUM AND MINIMUM TEMPERATURE AND HUMIDITY IN SEVERAL PARTS OF THE COMMONWEALTH OF AUSTRALIA.




EXPLANATION OF THE GRAPHS OF TEMPERATURE AND HUMIDITY.—In the above graphs, in which the heavy lines denote 'temperature' and the thin lines 'humidity,' the fluctuations of mean temperature and mean humidity are shewn throughout the year. These curves are plotted from the data given in the Climatological Tables hereinafter. The temperatures are shewn in degrees Fahrenheit, the inner columns giving the corresponding values in Centigrade degrees. Humidities have not been obtained for Port Darwin, Daly Waters, and Alice Springs.

For the thin lines the degree numbers represent relative humidities, or the actual percentages of actual saturation on the total for the respective temperatures.

The upper temperature line represents the mean of the maximum, and the lower line the mean of the minimum results; thus the curves also shew the progression of the range between maximum and minimum temperatures throughout the year. The humidity curves shew the highest and lowest values of the mean monthly humidity at 9 a.m. recorded during a series of years.

INTERPRETATION OF THE GRAPHS.—The curves denote mean monthly values. Thus, taking, for example, the temperature graphs for Perth, the mean readings of the maximum and minimum temperatures for a number of years on 1st January would give respectively about 83° Fahr. and 62° Fahr. Thus the mean range of temperature on that date is the difference, viz., 21°. Similarly, observations about 1st June would give respectively about 66° Fahr. and 51° Fahr., or a range of 15°.

In a similar manner it will be seen that the greatest mean humidity, say for March, is about 62° and the least mean humidity for the month 48°; in other words, at Perth, the degree of saturation of the atmosphere by aqueous vapour for the month of March ranges between 62 % and 48 %.

FIG. 55.

(5) *Melbourne.*—The mean annual humidity derived from the 9 a.m., 3 p.m., and 9 p.m. observations in Melbourne is 71 ; the greatest monthly average, 88, in June and July, 1858 ; and the lowest, 49, in December, 1908.

(6) *Hobart.*—Hobart's mean annual humidity at 9 a.m. is 71 ; the highest monthly mean, 92, in June ; and the lowest, 51, in February and December.

From the above results it is seen that in respect to relative humidity, Sydney has the first place, while Hobart, Melbourne, Brisbane, Perth, and Adelaide follow in the order stated, Adelaide being the driest. The graphs shown on Fig. 55 show the annual variations in humidity. It will be observed that the relative humidity is ordinarily, but not invariably, great when the temperature is low.

N.B.—For the thin lines (relative humidities), the degree numbers represent the percentages of possible saturation.

## VII.—SPECIAL FACTORS CONTROLLING CLIMATE.

Before considering the vital question of rainfall, which our study of temperature and barometric changes now enables us to do, it may be well to glance at two factors of considerable importance in this connexion.

*Ocean Currents* certainly affect the coastal climates to a great extent, while the *topography* practically determines the local deviations from the general simple curves of the isohyets around the heart of the continent.

### Ocean Currents.

Sub-dividing the coast into six regions, as in the case of the winds, and comparing the charts issued for the U.S.A. and British pilots, we get a fair idea of the variability of the currents in some of these regions.

*Northern Coasts.*—A fairly constant flow from east to west characterizes the winter (April, May, June, July, and August). It will not affect the climate of Northern Australia appreciably. During the rest of the year east and west currents seem both to occur in coastal waters.

*Queensland Coast.*—During winter and spring (May–October), there is a fairly permanent set to the south-east. This brings warmer waters in temperate regions. During summer streams seem to show a tendency to flow north-westward along the Barrier Reefs.

*New South Wales Coast.*—Generally a flow to the southward, but varying especially in midwinter. This has a tendency to warm the coast lands.

*South Australian Coast.*—A very general westerly drift, but in the Bight the streams vary considerably, especially in Autumn (February–June). There is a southern component in this current, so that the result is to cool the southern shores of Australia.

*South-west Coast.*—A fairly steady current from the south-west most of the year. In winter it appears less constant, and during April–July eddies near the coast, and exhibits a movement to the south. This is a definitely cool current on the whole.

*North-west Coast.*—The same condition as along the south-west coast; hence a cold-water current occurs, but not so important as further south.

## Topography and its Effect on Climate.

A contour map of Australia shows that the continent is strikingly devoid of strong contrasts. Three-quarters of the land mass lies between the 600 and 1,500 feet contours in the form of a huge plateau. Of the remainder, there is a low-lying area comprising the Murray and Lake Eyre Basins, partly separated by the Flinders and Barrier Ranges, and, secondly, a fringe of land with an elevation of 2,000 or 3,000 feet, culminating in 7,000 feet at Mt. Kosciusko, extending through Victoria, Eastern New South Wales, and Eastern Queensland. Isolated elevated areas such as the MacDonnell and Musgrave Ranges in Central Australia, and others in Ashburton, Kimberley, Arnhem Land reach 3,000 or 4,000 feet, but are usually of the nature of bulges on the surface of the plateau rather than true mountain ranges.

Surrounding the central dry area of Australia, the isohyets describe almost concentric curves, any modifications being almost entirely due to variations in elevation. Thus, the Darling Ranges to a great degree account for the excellent rainfall of the south-west corner of Australia. The Flinders Range (South Australia) and Australian Alps in the south-east have heavier rainfalls than the surrounding tracts owing to their cooling effect on the air currents. Along the eastern elevated margin of Australia every ridge between large river valleys accounts for a somewhat greater rainfall. Examples of the latter type are the Peak Range and Darling Downs in Queensland. Where the eastern ranges of Northern Queensland (Bellenden Ker, 5,000 feet) obstruct the South-east Trade Winds, there occurs the heaviest rainfall (165.58 inches) in Australia. In Western Tasmania there is a superfluity of rain for similar reasons, though here, the constant "stormy westerlies" play the part of water bearers.

A brief notice may be devoted to the south-east corner of Australia where, in only 15 per cent. of the total area, no less than 85 per cent. of the population of the continent dwells. Here the contours have been very approximately charted and the occurrence of alternating areas of a drier and wetter type than normal is a very interesting and marked feature. In the map shown on Fig. 56, it will be noticed that the so-called Dividing Range in the south consists really of five or six more or less disconnected "massifs." In the north is the largest of all—The New England Plateau. Then a broad low gap (near Cassilis), of much physiographic importance, and hence specially named a Geocol, separates the first massif from the Blue Mountain massif. Another geocol around Lake George is the northern boundary of two well-marked mountain areas. These latter—the Snowy and Tindery Ranges—are separated by a long north-south fault valley, or subsidence area, which has been named the Australian Rift Valley, with its summit at the Cooma Geocol.

The Snowy Mountains continue as the Bowen Mountains in Victoria, and are separated from the more eastern massif (the Barry Mountains) by the Omeo Geocol. At Kilmore the cordillera practically finishes, though a well-marked low plateau near Ballarat prolongs the main divide to the westward.

If we now consider the distribution of rainfall, we shall recognise how closely it is bound up with this alternation of a highland and geocol.

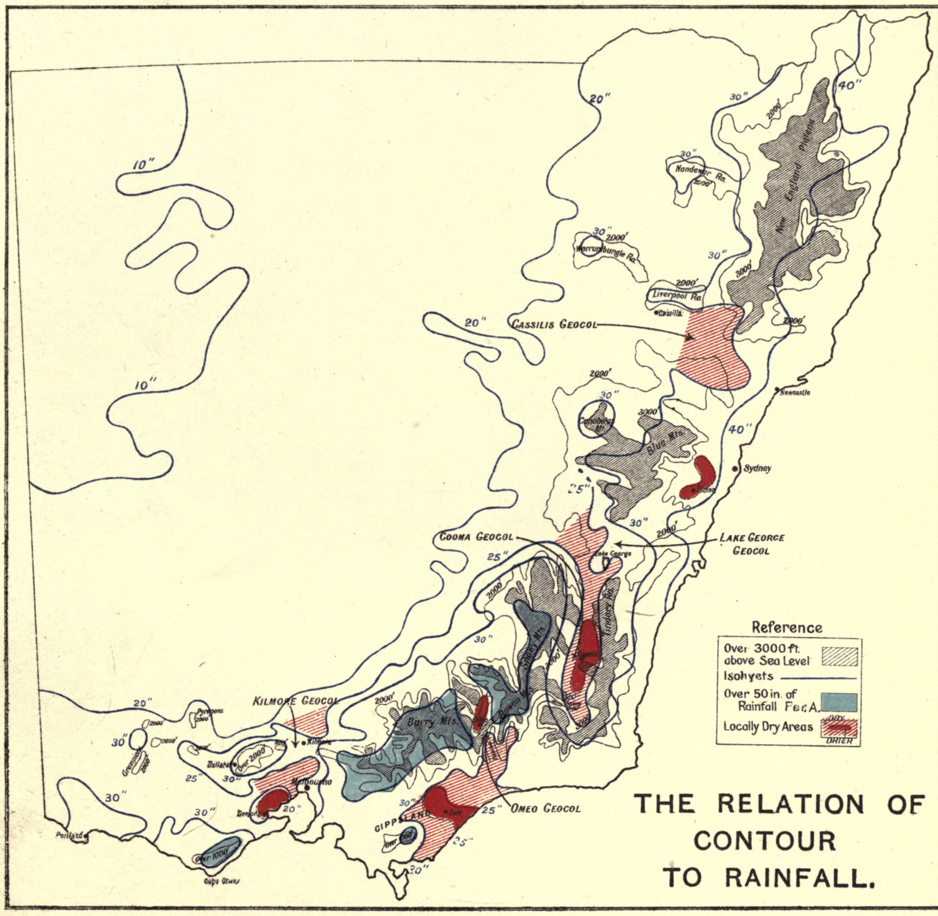

THE RELATION OF
CONTOUR
TO RAINFALL.
Reference
Over 3000 ft. above Sea Level
Isohyets
Over 50 in. of Rainfall Per A.
Locally Dry Areas
CASSILIS GEOCOL
COOMA GEOCOL
LAKE GEORGE GEOCOL
KILMORE GEOCOL
OMEO GEOCOL
New England Plateau
Blue Mts.
Liverpool Ra.
Warrumbungle Ra.
Nandewar Ra.
Newcastle
Sydney
Lake George
Barry Mts.
Melbourne
Kilmore
Ballarat
GIPPSLAND
Portland
Cape Otway
10"
20"
25"
30"
40"
2000'
3000'

FIG. 56.

This is perhaps shown most graphically in a table :—

| | Name. | Height. | Rainfall. |
|---|---|---|---|
| Wet | New England Plateau .. .. | 3,000 ft. + | 30–40 in. |
| Dry | Cassilis Geocol .. .. .. | 1,000–2,000 ft. | 20–30 in. |
| Wet | Blue Mountain area .. .. .. | 3,000 ft. + | 30–40 in. |
| Dry | Lake George Geocol .. .. .. | 2,000 ft. | 20–25 in. |
| Wet | Tindery Range .. .. .. | 3,000–5,000 ft. | 25–30 in. |
| Dry | Cooma Geocol .. .. .. | 2,000–3,000 ft. | Under 20 in. |
| Wet | Snowy Ranges .. .. .. | 3,000–7,000 ft. | Over 50 in. |
| Dry | Omeo Geocol .. .. .. | 2,000–3,000 ft. | 20–30 in. |
| Wet | Barry Mountains .. .. .. | 3,000–5,000 ft. | Over 50 in. |
| Dry | Kilmore Geocol .. .. .. | 1,200 ft. | 25 in. |
| Wet | Ballarat Uplands .. .. .. | 2,000 ft. | 30 in. |

One or two other isolated areas deserve brief mention. The noticeable effect (in the far West) of the comparatively low Grampians and Cape Otway Ranges on the rainfall is very evident. The latter, though less than 2,000 feet high, lead to precipitations of over 50 and at a few stations nearly 80 inches annually. Near Geelong is one of the peculiar *locally dry* areas, due no doubt to its occupying a low-lying situation, sheltered from north, south, and north-west winds.

A similar occurrence of heavy rainfall (50 inches) on the insignificant Gippsland Hills (1,000–2,000 feet) seems to have robbed the atmosphere of the moisture due to the more eastern regions around Sale. The latter has 5 inches less rainfall than the rest of Eastern Victoria.

We have noticed the dry belt in the Omeo region, and the similar but larger dry belt in the Cooma Valley (The Rift). Behind Sydney is a very interesting patch extending from Picton to the Emu Plains, with less than 30 inches. This area lies between the Blue Mountains and the highlands about Bowral and Moss Vale. The former intercept the westerly rains, the latter those coming from the south-east.

The volcanic ranges of the Warrumbungles and Nandewars also give rise to considerable increase in the rainfall in the vicinity.

Similar relations of great local importance must necessarily obtain in the other regions of the continent, but absolutely no data of the contours is available for the comparison.

## VIII.—CHIEF CLIMATIC REGIONS.

Our study of the chief weather elements has shown us that Australia has not one general climate, but contains within its vast area several types of climate. They may be classified according to many factors ; such as amounts of rainfall, seasons of rainfall, dominant winds, topography, &c., &c. A combination of the first two criteria seems to furnish the best primary division, while the less important factors will determine the secondary subdivision.

The proposed scheme may be tabulated as follows :—

Australia.

Dry Region.
(Under 10 inches).

Northern Moiety
(Summer rain)

Southern Moiety
(Winter rain)

Wet Region.
(Over 10 inches).

Monsoon Region
(Summer rains)

(Subdivision)
E. Coast Trade
Wind Region

(Subdivision)
Autumn Maxi-
mum Region

Uniform rains

Winter rains

These subdivisions are shown in Fig. 58.

## Monsoon Region.

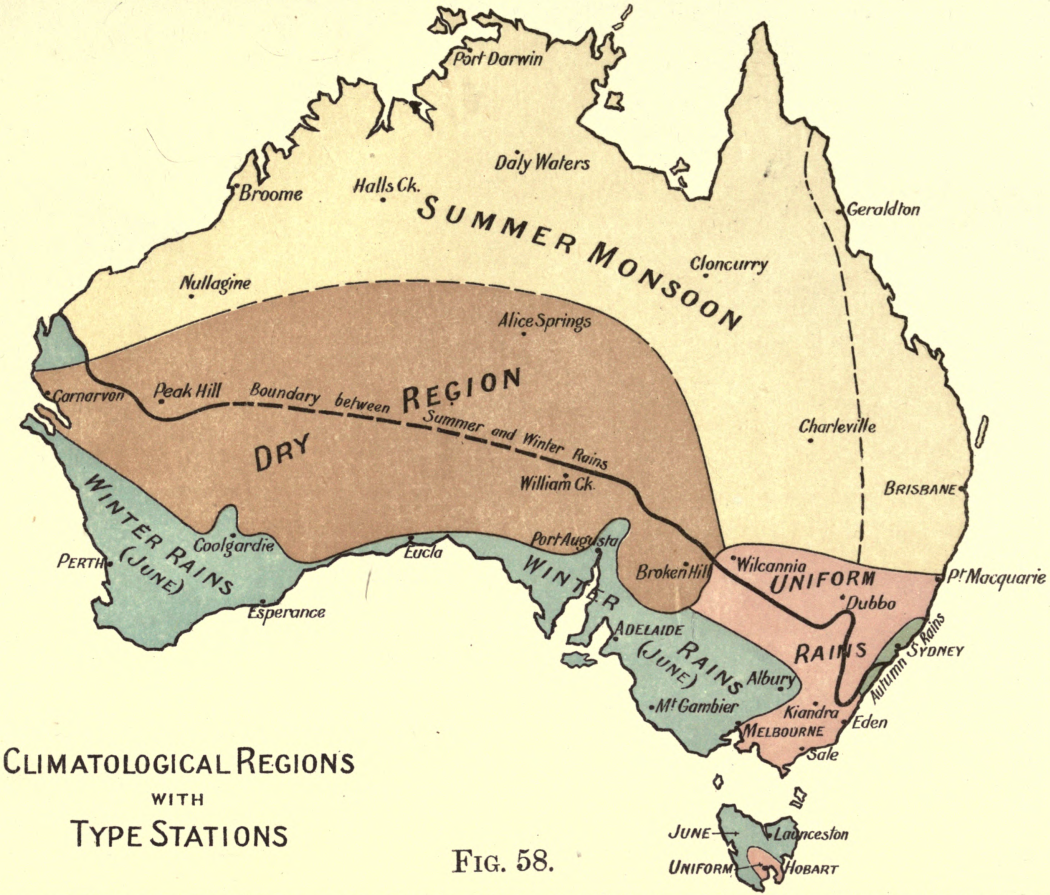
This comprises the whole of Australia north of the Tropic of Capricorn together with Southern Queensland and the north of New South Wales, The heaviest rains are in January and February. They are directly due to the indraught caused by the heating of the centre of the continent. This leads to the formation of a locus of low pressure (monsoonal depression) in Northern Australia, and the ascending winds are cooled and deposit their water vapour in heavy rain storms and thunder showers.

Over the greater portion of the area the winter is usually quite dry, and practically the whole of the rain falls in three or four months. But in the east, owing to two special controls, the rain is much more abundant and uniform. Along the Queensland coast the land rises to considerable heights, and there is a very permanent onshore wind—the South-east Trade. This leads to a rainfall of over an inch each month in the winter, while the rest of the summer rain region is receiving nothing. It seems worth while therefore to separate this eastern fringe as a subdivision of the summer rain (or monsoon) region.

Meteorological data are given in the following table for type stations in this region:—

| Station. | State. | Height. | Description. |
|---|---|---|---|
| | | Feet. | |
| Broome .. | Western Australia.. | 63 | A coastal town, subject to hurricanes |
| Hall's Creek .. | Western Australia.. | 1,225 | An inland mining township (200 miles from coast) |
| Darwin .. | Northern Territory | .. | Capital of Northern Territory (on the coast) |
| Daly Waters .. | Northern Territory | .. | An inland settlement on Overland Telegraph (300 miles from coast) |
| Cloncurry .. | Queensland .. | 696 | An inland town (200 miles south from Gulf of Carpentaria) |
| Charleville .. | Queensland .. | 975 | A town in South Queensland (300 miles from the Pacific coast) |
| *Harvey Creek .. | Queensland .. | .. | A coastal town with heaviest rainfall in Australia (25 miles south of Cairns) |
| Brisbane .. | Queensland .. | 137 | Capital of Queensland ; in the south-east, about 10 miles up the Estuary |

N.B.—As pressure and temperature normals are not available for Harvey Creek those for Cairns have been substituted.




CLIMATOLOGICAL REGIONS
WITH
TYPE STATIONS

FIG. 58.

## Types of the Summer Rain Region.

*Pressure.*†

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | |
| Broome, Western Australia .. | 29·721 | 29·731 | 29·758 | 29·847 | 29·920 | 29·950 | 29·962 | 29·951 | 29·908 | 29·860 | 29·792 | 29·748 | 29·846 | 15 |
| Hall's Creek, Western Australia .. | 29·720 | 29·737 | 29·787 | 29·890 | 29·982 | 30·012 | 30·016 | 29·982 | 29·916 | 29·853 | 29·788 | 29·742 | 29·869 | 12 |
| Darwin, Northern Territory .. | 29·701 | 29·710 | 29·746 | 29·796 | 29·851 | 29·881 | 29·897 | 29·895 | 29·864 | 29·829 | 29·780 | 29·727 | 29·806 | 31 |
| Cloncurry, Queensland .. .. | 29·714 | 29·756 | 29·823 | 29·948 | 30·042 | 30·077 | 30·082 | 30·076 | 30·009 | 29·934 | 29·866 | 29·783 | 29·926 | 12 |
| Charleville, Queensland .. | 29·815 | 29·874 | 29·938 | 30·074 | 30·169 | 30·181 | 30·170 | 30·165 | 30·096 | 30·041 | 29·950 | 29·857 | 30·028 | 9 |
| Cairns, Queensland .. .. | 29·752 | 29·805 | 29·826 | 29·923 | 30·007 | 30·050 | 30·028 | 30·048 | 30·023 | 30·003 | 29·930 | 29·840 | 29·934 | 9 |
| Brisbane, Queensland .. .. | 29·898 | 29·927 | 29·988 | 30·083 | 30·138 | 30·105 | 30·108 | 30·138 | 30·077 | 30·046 | 30·003 | 29·923 | 30·036 | 26 |

† Note.—The normals for Queensland stations refer to 9 a.m. observations only; the others are the means of 9 a.m. and 3 p.m. observations.

## Types of the Summer Rain Region.

*Temperature.**

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | |
| Broome, Western Australia .. | 85·9 | 85·4 | 85·4 | 83·1 | 76·4 | 71·2 | 70·3 | 72·4 | 77·0 | 81·0 | 84·6 | 85·9 | 79·8 | 16 |
| Hall's Creek, Western Australia .. | 87·0 | 85·6 | 82·6 | 77·7 | 70·8 | 65·6 | 64·7 | 69·0 | 76·2 | 83·4 | 86·9 | 87·0 | 78·0 | 14 |
| Darwin, Northern Territory .. | 84·0 | 83·5 | 84·2 | 84·2 | 81·8 | 77·3 | 77·2 | 79·4 | 83·0 | 85·2 | 85·7 | 85·3 | 82·6 | 37 |
| Daly Waters, Northern Territory | 86·9 | 85·5 | 83·8 | 80·2 | 74·7 | 70·1 | 68·6 | 72·7 | 79·8 | 86·1 | 88·2 | 88·1 | 80·4 | 27 |
| Cloncurry, Queensland .. .. | 87·3 | 85·0 | 83·1 | 77·8 | 71·0 | 64·2 | 61·5 | 67·0 | 72·8 | 82·5 | 85·2 | 88·0 | 77·1 | 12 |
| Charleville, Queensland .. | 82·9 | 80·7 | 76·1 | 68·7 | 60·1 | 53·7 | 51·1 | 56·6 | 62·8 | 71·6 | 77·5 | 80·4 | 68·5 | 10 |
| Cairns, Queensland .. .. | 81·7 | 81·1 | 79·7 | 77·1 | 73·6 | 70·5 | 69·8 | 70·0 | 73·0 | 76·2 | 78·5 | 81·3 | 76·0 | 8 |
| Brisbane, Queensland .. .. | 77·2 | 76·5 | 74·3 | 70·2 | 64·4 | 60·0 | 58·0 | 60·5 | 65·1 | 69·8 | 73·3 | 76·4 | 68·8 | 26 |

* The means of maxima and minima.

TYPES OF THE SUMMER RAIN REGION.

*Rainfall.*

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Total for Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | |
| Broome, Western Australia .. | 4·96 | 6·35 | 3·77 | 1·35 | ·41 | 1·22 | ·27 | ·04 | ·08 | ·03 | ·93 | 3·55 | 22·96 | 23 |
| Hall's Creek, Western Australia .. | 5·28 | 4·73 | 2·92 | 1·18 | ·41 | ·24 | ·25 | ·12 | ·16 | ·59 | 1·36 | 3·43 | 20·67 | 22 |
| Darwin, Northern Territory .. | 15·27 | 13·05 | 9·70 | 4·50 | ·75 | ·16 | ·07 | ·11 | ·48 | 2·12 | 5·21 | 10·30 | 61·72 | 43 |
| Daly Waters, Northern Territory | 6·12 | 6·71 | 5·02 | 1·04 | ·15 | ·34 | ·07 | ·15 | ·29 | ·83 | 2·15 | 4·08 | 26·95 | 40 |
| Cloncurry, Queensland .. .. | 4·94 | 5·07 | 2·60 | ·86 | ·42 | ·44 | ·46 | ·10 | ·44 | ·46 | 1·13 | 2·99 | 19·91 | 23 |
| Charleville, Queensland.. .. | 2·49 | 3·14 | 3·23 | 1·46 | 1·41 | 1·33 | ·94 | ·58 | ·81 | 1·29 | 1·34 | 2·26 | 20·28 | 23 |
| Harvey Creek, Queensland .. | 30·87 | 22·18 | 32·19 | 22·20 | 13·20 | 7·98 | 4·22 | 5·42 | 3·68 | 3·81 | 8·10 | 11·73 | 165·58 | 16 |
| Brisbane, Queensland .. .. | 6·66 | 6·63 | 6·20 | 3·64 | 2·92 | 2·62 | 2·33 | 2·35 | 2·05 | 2·78 | 3·65 | 5·12 | 46·95 | 61 |

## Dry Region.

This is bounded somewhat arbitrarily by the 10-in. annual isohyet. Two areas within the tract as plotted have more than 10 inches—in the north-east, the highlands of the MacDonnell Ranges, and in the north-west the Peak Hill Gold-field.

These two relatively wet areas may be related with the two favorite paths of the tropical "lows"; which often curve southward and south-eastward over Pilbara and Western Queensland respectively.

Owing to lack of information the northern boundary of the dry region cannot be accurately plotted, so that the line given—from Winning Pool to Barrow Creek—will, no doubt, need considerable revision later. Although the scattered rains of the north fall chiefly in January, and of the south in May and June, this variation does not determine the type of vegetation which is almost wholly controlled by absence of rain (xerophilous), and not by the season when it falls. The dry region, which consists mainly of an undulating tableland 1,000–3,000 feet high, forms therefore a united whole.

If the isohyets for 0·5 inches are plotted in each month (not shown in Figs. 39 to 50), the MacDonnell Ranges are seen to form an "oasis" in the arid region. In May, June, October, and November, when the districts not only south but east (Sturt's Desert, &c.) are receiving less than half-an-inch this region of uplands (3,000 feet) is favoured by more rainfall. Possibly the Musgrave Ranges—which are said to reach 5,000 feet (Mt. Woodroffe, 5,230 feet), also benefit in a similar degree, but no data are available.

The driest region so far furnished with rain-gauges lies east and north-east from Lake Eyre, where less than 5 inches is the average annual rainfall. This minimum rainfall is coincident with the lowest elevation, Lake Eyre being actually below sea-level, 39 feet.

In the northern moiety of the dry region the temperatures are of course much more severe than in the southern, for, as we have seen, the hottest portion of Australia lies between the Peak Hill and Pilbara Gold-fields. The evaporation is therefore much greater here than in the southern gold-fields—an important factor in connexion with the water supply of these centres. (Compare Wiluna and Coolgardie in the following table):—

EVAPORATION DATA.

| Station. | Years. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Total Evaporation. | Annual Rainfall. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Carnarvon .. .. | 4 | 14·6 | 11·9 | 10·8 | 8·3 | 5·3 | 4·3 | 5·0 | 6·4 | 7·5 | 10·0 | 11·8 | 13·4 | 109·3 | 9·05 |
| Wiluna .. .. | 8 | 21·4 | 17·7 | 15·7 | 10·6 | 7·3 | 4·7 | 5·0 | 6·7 | 9·5 | 14·3 | 18·3 | 21·7 | 152·9 | 9·76 |
| Coolgardie .. .. | 14 | 13·1 | 10·6 | 9·3 | 6·2 | 3·8 | 2·5 | 2·5 | 3·5 | 5·3 | 7·5 | 10·3 | 13·1 | 87·74 | 9·09 |

N.B.—Coolgardie, 36″ tank with water jacket. Carnarvon and Wiluna, 8″ dishes with small water jacket. No satisfactory determination of the factor required to relate evaporation results from these different experiments has yet been made, but it is probable that the 8″ dish will give results from 5 to 15 per cent. in excess of those of the tank.

In the following tables, the meteorological data for a number of typical stations in the dry region are given:—

| Station. | State. | Height. | Description. |
|---|---|---|---|
| | | Feet. | |
| Carnarvon .. .. .. | Western Australia.. .. .. | 15 | The driest coastal town in Australia |
| Nullagine .. .. .. | Western Australia.. .. .. | 1,265 | Inland town (150 miles from coast). Characterized by intense summer heat |
| Peak Hill .. .. .. | Western Australia.. .. .. | 1,930 | Inland town (300 miles from coast) |
| Coolgardie .. .. .. | Western Australia.. .. .. | 1,389 | On the south-east boundary of the dry region (330 miles from coast) |
| Alice Springs .. .. | Northern Territory .. .. | 2,000 | In the Central Highlands (600 miles from coast) |
| William Creek .. .. | South Australia .. .. .. | 250 | Near Lake Eyre (250 miles from coast) |
| Broken Hill .. .. | New South Wales .. .. | 1,000 | Near the south-west boundary (200 miles from coast) |

### Types of the Dry Region.

*Pressure.*†

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | |
| Carnarvon, Western Australia .. | 29·790 | 29·798 | 29·848 | 29·947 | 30·019 | 30·038 | 30·070 | 30·069 | 30·030 | 29·990 | 29·912 | 29·822 | 29·944 | 15 |
| Nullagine, Western Australia .. | 29·690 | 29·711 | 29·787 | 29·906 | 29·992 | 30·042 | 30·056 | 30·024 | 29·944 | 29·874 | 29·772 | 29·704 | 29·875 | 13 |
| Peak Hill, Western Australia .. | 29·702 | 29·726 | 29·808 | 29·929 | 30·023 | 30·064 | 30·079 | 30·051 | 29·968 | 29·898 | 29·792 | 29·710 | 29·896 | 14 |
| Coolgardie, Western Australia .. | 29·866 | 29·900 | 29·957 | 30·070 | 30·106 | 30·096 | 30·111 | 30·103 | 30·024 | 29·974 | 29·913 | 29·858 | 29·999 | 15 |
| Alice Springs, Northern Territory | 29·708 | 29·736 | 29·846 | 29·984 | 30·072 | 30·106 | 30·122 | 30·056 | 29·972 | 29·887 | 29·804 | 29·742 | 29·920 | 30 |
| Broken Hill, New South Wales .. | 29·875 | 29·905 | 29·962 | 30·120 | 30·154 | 30·163 | 30·114 | 30·142 | 30·042 | 30·030 | 29·934 | 29·860 | 30·025 | 5 |

† The normals for Broken Hill refer to 9 a.m. observations only; the others are the means of 9 a.m. and 3 p.m. observations.

### Types of the Dry Region.

*Temperatures.**

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | |
| Carnarvon, Western Australia .. | 79·8 | 80·6 | 79·4 | 74·7 | 67·9 | 62·7 | 60·6 | 62·6 | 65·6 | 69·0 | 73·0 | 76·9 | 71·1 | 15 |
| Nullagine, Western Australia .. | 89·8 | 88·6 | 84·2 | 77·3 | 68·5 | 61·1 | 59·3 | 63·9 | 71·0 | 78·2 | 85·8 | 88·8 | 76·4 | 14 |
| Peak Hill, Western Australia .. | 87·6 | 86·2 | 82·1 | 74·0 | 63·8 | 56·5 | 54·7 | 58·9 | 65·0 | 71·8 | 80·3 | 86·2 | 72·3 | 14 |
| Coolgardie, Western Australia .. | 77·5 | 76·0 | 71·6 | 65·4 | 57·6 | 52·3 | 50·8 | 53·4 | 58·4 | 63·6 | 70·9 | 76·2 | 64·5 | 16 |
| Alice Springs, Northern Territory | 84·0 | 82·3 | 76·9 | 68·0 | 59·7 | 54·2 | 52·5 | 58·5 | 65·5 | 73·6 | 79·5 | 82·5 | 69·8 | 34 |
| William Creek, South Australia .. | 82·7 | 82·5 | 76·1 | 67·2 | 59·2 | 53·9 | 52·2 | 56·2 | 62·4 | 70·3 | 77·1 | 81·4 | 68·4 | 24 |
| Broken Hill, New South Wales .. | 78·4 | 77·9 | 71·8 | 63·9 | 56·6 | 51·0 | 49·2 | 52.8 | 58·4 | 65·8 | 73·0 | 76·6 | 64·6 | 21 |

* The means of maxima and minima.

### Types of the Dry Region.

*Rainfall.*

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Total for Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | |
| Carnarvon, Western Australia .. | ·30 | ·70 | ·45 | ·52 | 1·29 | 2.83 | 1·87 | ·63 | ·25 | ·08 | ·04 | ·09 | 9·05 | 30 |
| Nullagine, Western Australia .. | 2·67 | 2·02 | 2·60 | 1·04 | ·55 | 1·13 | ·70 | ·46 | .01 | ·00 | ·39 | 1·17 | 12·74 | 15 |
| Peak Hill, Western Australa .. | 1·39 | 1·06 | 1·25 | 1·23 | 1·01 | 1·35 | ·86 | ·62 | ·20 | ·14 | ·19 | ·43 | 9·73 | 15 |
| Coolgardie, Western Australia .. | ·37 | ·69 | ·65 | ·64 | 1·35 | 1·18 | ·87 | ·90 | ·61 | ·69 | ·52 | ·62 | 9·09 | 20 |
| Alice Springs, Northern Territory | 1·68 | 1·73 | 1·24 | ·90 | ·60 | ·57 | ·46 | ·40 | ·41 | ·72 | ·90 | 1·32 | 10·93 | 39 |
| William Creek, South Australia .. | ·55 | ·41 | ·77 | ·45 | ·45 | ·69 | ·25 | ·29 | ·45 | ·33 | ·42 | ·35 | 5·41 | 39 |
| Broken Hill, New South Wales .. | ·76 | ·84 | ·63 | ·72 | ·87 | 1·41 | ·66 | ·97 | ·68 | ·84 | ·71 | ·80 | 9·89 | 24 |

## Intermediate Region of Uniform Rains.

In our description of the monthly rainfall we saw that the distribution areas were shaped like crescents. The summer rain crescent includes Northern Australia and South-eastern Australia; the winter rain crescent includes South-western Australia and South-eastern Australia. In other words, the two crescents do not meet in the north-west—so far as any but light rains are concerned—but overlap in the south-east. Hence the central coastal *aridity* in Western Australia, and the region of *uniform* monthly rainfall in Eastern Australia.

The latter region is a somewhat triangular area reaching from Wilcannia east to the coast at Port Macquarie, and south-east to Albury and thence to Melbourne. A reference to the following tables shows that Dubbo is the typical station, for, as already noted, it has just under 2 inches of rainfall each month of the year. Cobar and Wilcannia to the north-west and Goulburn and Delegate to the south-east are also on the axis of uniformity. To the north-east the summer rains grow proportionately greater—though a considerable amount of rain falls all the winter. To the south-west the June maximum becomes very evident—and West or South-west from the Grampians the winter rainfall is more than double that of summer.

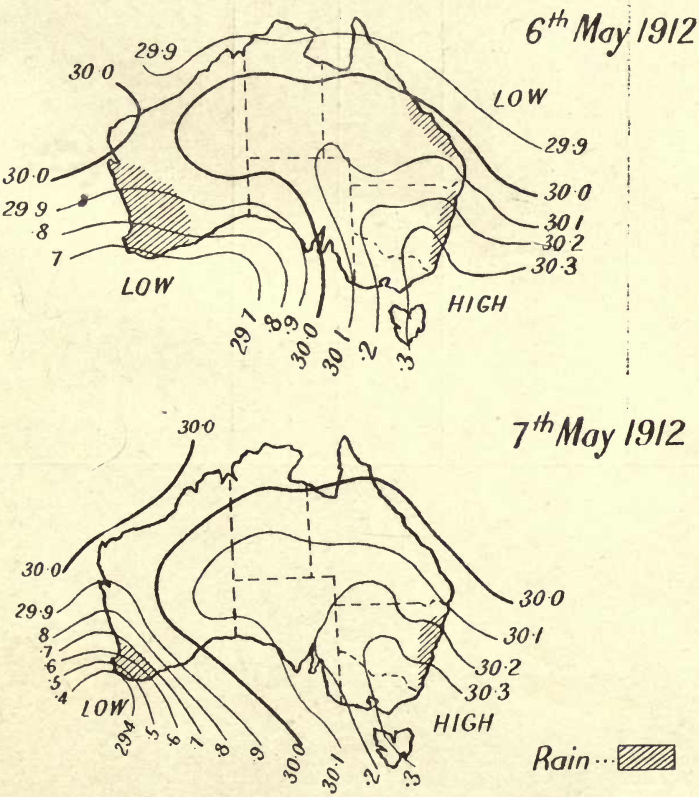



Fig. 59.
Anticyclone causing south-easterly winds and rain in coastal district of New South Wales.

Furthermore, along the coast from Port Stephens to Ulladulla is an "enclave" of autumn rains. This includes Sydney, and forms a narrow coastal strip with heavy rains in February, March, April, May, and June, and moderate rains in the remaining months. An explanation of this is suggested in the following paragraphs, based on conditions in 1912.

During these autumn months the anticyclones move along latitudes of about 35° S. (In midwinter this path is along 28° and in midsummer along 42°. In spring the paths are much the same as in autumn.)

About once a week during the autumn months of 1912 this coastal strip experienced rains, while the rest of New South Wales was dry. This rain generally accompanied south-east on-shore winds, in the front and north of a *high*, as shown in Fig. 59. Out of nineteen examples of this type of rain distribution, in autumn, 1912, no less than fifteen occurred when the "*high*" was centred about the Bass Straits. (Roughly, between Mt. Gambier and Gabo.)

Meteorological data for the following stations is given in the tables :—

| Town. | State. | Height. | Distance from Coast. | Description. |
|---|---|---|---|---|
| | | Feet. | Miles. | |
| Wilcannia | New South Wales | 267 | 300 | An inland town in the Western Plains |
| Dubbo .. | New South Wales | 870 | 200 | On the western slopes of the Divide |
| Newcastle .. | New South Wales | .. | .. | Coastal town near boundary of uniform regions and autumn rains |
| Sydney .. | New South Wales | 146 | .. | Capital, on the coast, with autumn maximum |
| Moruya .. | New South Wales | .. | .. | Coastal town in the south |
| Yass .. | New South Wales | 1,650 | 100 | On the western slopes of the Divide |
| Kiandra .. | New South Wales | 4,640 | 100 | Highest town in Australia |
| Sale .. | Victoria .. | .. | .. | Coastal town in drier region of Gippsland |
| Melbourne .. | Victoria .. | 115 | .. | Capital, at south-west corner of uniform region |
| Hobart .. | Tasmania .. | 160 | .. | Capital, on south-east of island |

### Types of the Uniform Rain Region.

*Pressure.* †

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | |
| Wilcannia, New South Wales .. | 29·888 | 29·920 | 30·016 | 30·124 | 30·177 | 30·153 | 30·172 | 30·147 | 30·097 | 30·033 | 29·984 | 29·913 | 30·052 | 30 |
| Dubbo, New South Wales .. | 29·899 | 29·935 | 30·017 | 30·117 | 30·173 | 30·135 | 30·153 | 30·144 | 30·079 | 30·020 | 29·958 | 29·896 | 30·044 | 29 |
| Newcastle, New South Wales .. | 29·915 | 29·961 | 30·038 | 30·095 | 30·107 | 30·082 | 30·109 | 30·103 | 30·041 | 30·002 | 29·974 | 29·905 | 30·028 | 50 |
| Sydney, New South Wales .. | 29·930 | 29·975 | 30·051 | 30·108 | 30·116 | 30·080 | 30·116 | 30·105 | 30·045 | 30·003 | 29·971 | 29·916 | 30·035 | 51 |
| Moruya, New South Wales .. | 29·908 | 29·966 | 30·031 | 30·056 | 30·092 | 30·033 | 30·069 | 30·086 | 29·994 | 29·960 | 29·949 | 29·881 | 30·002 | 35 |
| Sale, Victoria .. .. .. | 29·879 | 29·961 | 30·018 | 30·050 | 30·098 | 30·057 | 30·042 | 30·054 | 29·949 | 29·918 | 29·931 | 29·897 | 29·988 | 17 |
| Melbourne, Victoria .. .. | 29·913 | 29·962 | 30·037 | 30·101 | 30·106 | 30·078 | 30·097 | 30·067 | 29·996 | 29·965 | 29·952 | 29·896 | 30·014 | 55 |
| Hobart, Tasmania .. .. | 29·849 | 29·942 | 29·969 | 29·971 | 30·016 | 29·974 | 29·951 | 29·954 | 29·866 | 29·856 | 29·821 | 29·819 | 29·916 | 28 |

† The normals for New South Wales stations and Hobart refer to 9 a.m. observations only; the Melbourne and Sale normals are the equivalent hourly means deduced from 9 a.m., 3 p.m., and 9 p.m. observations.

### Types of the Uniform Rain Region.

*Temperatures.* *

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | |
| Wilcannia, New South Wales .. | 81·4 | 79·9 | 74·0 | 65·4 | 57·7 | 52·3 | 50·0 | 53·9 | 60·2 | 68·2 | 74·8 | 79·4 | 66·4 | 27 |
| Dubbo, New South Wales .. | 78·6 | 77·0 | 70·8 | 64·0 | 55·2 | 49·6 | 47·4 | 50·6 | 56·2 | 63·4 | 70·9 | 76·1 | 62·7 | 35 |
| Newcastle, New South Wales .. | 73·0 | 72·4 | 71·0 | 66·4 | 60·3 | 56·0 | 54·0 | 56·2 | 60·4 | 64·9 | 68·6 | 71·5 | 64·6 | 47 |
| Sydney, New South Wales .. | 71·6 | 71·0 | 69·2 | 64·5 | 58·6 | 54·3 | 52·3 | 54·8 | 58·8 | 63·4 | 67·0 | 70·0 | 63·0 | 54 |
| Moruya, New South Wales .. | 69·0 | 68·6 | 67·2 | 63·2 | 57·1 | 53·0 | 51·8 | 53·6 | 56·9 | 60·2 | 63·9 | 66·4 | 60·9 | 37 |
| Sale, Victoria .. .. .. | 65·8 | 66·5 | 63·1 | 58·4 | 53·2 | 49·1 | 47·5 | 49·9 | 52·4 | 56·0 | 61·4 | 64·0 | 57·3 | 16 |
| Melbourne, Victoria .. .. | 67·5 | 67·3 | 64·7 | 59·5 | 54·1 | 50·3 | 48·4 | 51·0 | 54·0 | 57·5 | 61·3 | 64·5 | 58·3 | 57 |
| Hobart, Tasmania .. .. | 62·4 | 62·4 | 59·5 | 55·1 | 50·4 | 46·8 | 45·3 | 47·7 | 50·8 | 53·9 | 57·5 | 60·3 | 54·3 | 42 |

* The means of maxima and minima, except for Sale, in which case the normals are the equivalent hourly means deduced from 9 a.m., 3 p.m., and 9 p.m. observations.

TYPES OF THE UNIFORM RAIN REGION.

*Rainfall.*

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Total for Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | |
| Wilcannia, New South Wales .. | 0·97 | 0·83 | 1·12 | 0·69 | 1·04 | 1·06 | 0·59 | 0·84 | 0·69 | 0·92 | 0·68 | 0·76 | 10·19 | 34 |
| Dubbo, New South Wales .. | 2·13 | 1·87 | 1·82 | 1·78 | 1·87 | 2·01 | 1·67 | 1·83 | 1·86 | 1·55 | 1·78 | 2·02 | 22·19 | 41 |
| Pt. Macquarie, New South Wales.. | 5·94 | 7·52 | 6·52 | 5·86 | 5·59 | 4·63 | 4·54 | 3·80 | 3·95 | 3·20 | 4·08 | 5·87 | 61·50 | 42 |
| Sydney, New South Wales .. | 3·67 | 4·70 | 5·07 | 5.24 | 4·95 | 5·18 | 4·68 | 3·29 | 2·89 | 2·82 | 2·91 | 2·60 | 48·00 | 54 |
| Moruya, New South Wales .. | 3·79 | 3·32 | 4·19 | 3·05 | 2·77 | 3·17 | 2·52 | 2·29 | 2·66 | 2·73 | 2·30 | 2·33 | 35·12 | 37 |
| Kiandra, New South Wales .. | 4·09 | 3·15 | 4·05 | 4·37 | 5·27 | 8·70 | 6·55 | 5·95 | 6·86 | 6·61 | 4·90 | 3·95 | 64·45 | 40 |
| Sale, Victoria .. .. .. | 2·05 | 1·52 | 1·96 | 1·90 | 1·83 | 2·33 | 1·88 | 2·01 | 2·30 | 2·20 | 2·14 | 2·12 | 24·24 | 24 |
| Melbourne, Victoria .. .. | 1·85 | 1·74 | 2·18 | 2·32 | 2·15 | 2·11 | 1·86 | 1·81 | 2·35 | 2·64 | 2·20 | 2·30 | 25·51 | 57 |
| Hobart, Tasmania .. .. | 1·80 | 1·45 | 1·65 | 1·80 | 1·91 | 2·22 | 2·10 | 1·83 | 2·14 | 2·24 | 2·50 | 1·93 | 23·57 | 70 |

## Winter Rain Region.

This region consists of a belt along the south coasts of Australia. It may be subdivided into four sections on geographical grounds, though the meteorology does not differ so much as might be expected—

(1) The south-west corner or Westralia Felix.

(2) The Bight Littoral.

(3) South Australian gulfs, Western Victoria, and the Riverina, New South Wales.

(4) Tasmania (except the south-east).

In these areas there is a strong maximum of rainfall in June, especially in the west. Along the Australian Bight the area receiving more than 10 inches is extremely narrow. The effect of the Flinders Range, which lies athwart the westerly winds, in improving the rainfall of South Australia is very strikingly shown. Probably the long "Rift" Gulf immediately to the west also tends to increase the rainfall hereabouts. In Victoria, the rainfall becomes more uniform towards the north-east.

Along the west coast of Tasmania is a region, unique in Australia, where a superabundance of rain has almost prohibited settlement. There are practically no inhabitants in the south-west region, which is very rugged country covered with an almost impenetrable scrub. The rainfall reaches 115 inches per year on the highlands behind Macquarie Harbor, and is therefore only exceeded at Harvey Creek and neighbouring stations in North Queensland.

Around Hobart is a small region having a much more uniform rainfall with a spring maximum.

Meteorological data for the following stations will indicate how the elements vary in the Winter Rain Region :—

| Town. | State. | Description. |
|---|---|---|
| Perth .. .. | Western Australia.. | Capital. On Melville Water, 10 miles from ocean |
| Esperance .. | Western Australia.. | On the south coast |
| Eucla .. .. | Western Australia.. | On the coast, at the head of the Great Australian Bight |
| Port Augusta .. | South Australia .. | On the coast, at the head of Spencer's Gulf |
| Adelaide .. | South Australia .. | Capital. On the east coast of St. Vincent's Gulf |
| Robe .. .. | South Australia .. | On the coast, in the south-east corner of South Australia |
| Albury .. | New South Wales | In the Eastern Riverina, 542 feet above sea-level |
| Launceston .. | Tasmania .. | On the Tamar Estuary, and 30 miles from the sea |

### Types of the Winter Rain Region.

*Pressure.*†

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. | Number of Years |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | |
| Perth, Western Australia .. | 29·911 | 29·927 | 29·990 | 30·074 | 30·079 | 30·065 | 30·096 | 30·088 | 30·057 | 30·034 | 29·994 | 29·932 | 30·021 | 28 |
| Esperance, Western Australia .. | 29·965 | 29·988 | 30·028 | 30·101 | 30·087 | 30·036 | 30·058 | 30·069 | 30·012 | 29·994 | 29·992 | 29·958 | 30·024 | 16 |
| Eucla, Western Australia .. | 29·924 | 29·952 | 30·017 | 30·087 | 30·101 | 30·081 | 30·110 | 30·067 | 30·020 | 29·981 | 29·962 | 29·919 | 30·018 | 34 |
| Port Augusta, South Australia .. | 29·874 | 29·906 | 29·998 | 30·102 | 30·137 | 30·119 | 30·148 | 30·105 | 30·038 | 29·983 | 29·945 | 29·887 | 30·020 | 33 |
| Adelaide, South Australia .. | 29·915 | 29·952 | 30·038 | 30·118 | 30·125 | 30·099 | 30·131 | 30·100 | 30·038 | 29·996 | 29·973 | 29·920 | 30·034 | 56 |
| Robe, South Australia .. .. | 29·933 | 29·978 | 30·037 | 30·095 | 30·127 | 30·055 | 30·050 | 30·058 | 29·987 | 29·963 | 29·971 | 29·926 | 30·015 | 23 |
| Albury, New South Wales .. | 29·883 | 29·959 | 30·015 | 30·084 | 30·110 | 30·092 | 30·097 | 30·094 | 30·018 | 29·969 | 29·932 | 29·869 | 30·010 | 43 |
| Cape Otway, Victoria .. .. | 29·918 | 29·965 | 30·031 | 30·043 | 30·075 | 30·030 | 30·040 | 30·011 | 29·967 | 29·940 | 29·934 | 29·899 | 29·988 | 46 |

† The normals for Albury refer to 9 a.m. observations only; those for Cape Otway are equivalent hourly means deduced from 9 a.m., 3 p.m., and 9 p.m. observations, and for the other stations the mean of 9 a.m. and 3 p.m.

### Types of the Winter Rain Region.

*Temperatures.**

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | |
| Perth, Western Australia .. | 73·6 | 74·2 | 71·2 | 66·4 | 60·4 | 56·2 | 55·0 | 56·0 | 57·9 | 60·9 | 65·4 | 70·6 | 64·0 | 16 |
| Esperance, Western Australia .. | 68·6 | 69·2 | 66·7 | 63·2 | 58·8 | 55·1 | 53·6 | 54·7 | 56·8 | 59·4 | 63·0 | 66·3 | 61·2 | 16 |
| Eucla, Western Australia .. | 70·9 | 71·2 | 69·3 | 66·1 | 60·9 | 55·9 | 54·3 | 56·3 | 59·3 | 62·7 | 65·9 | 69·3 | 63·5 | 35 |
| Port Augusta, South Australia .. | 77·5 | 78·1 | 73·3 | 66·3 | 59·8 | 54·5 | 52·8 | 55·6 | 60·4 | 66·7 | 72·2 | 75·8 | 66·1 | 24 |
| Adelaide, South Australia .. | 74·2 | 74·0 | 69·9 | 63·9 | 57·7 | 53·4 | 51·5 | 53·8 | 57·0 | 61·9 | 67·1 | 71·1 | 62·9 | 56 |
| Robe, South Australia .. .. | 64·7 | 65·0 | 62·1 | 58·7 | 55·6 | 52·4 | 50·8 | 52·0 | 53·8 | 56·7 | 60·1 | 62·3 | 57·8 | 23 |
| Albury, New South Wales .. | 76·2 | 74·3 | 69·3 | 60·4 | 52·1 | 47·8 | 45·9 | 49·0 | 53·8 | 60·1 | 66·9 | 71·9 | 60·7 | 43 |
| Launceston, Tasmania .. .. | 64·1 | 64·5 | 60·6 | 55·5 | 49·1 | 46·5 | 44·1 | 46·3 | 50·2 | 53·9 | 58·2 | 62·0 | 54·8 | 18 |

* The mean of maxima and minima.

## Types of the Winter Rain Region.

*Rainfall.*

| Station. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Total for Year. | Number of Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. | |
| Perth, Western Australia .. | ·33 | ·31 | ·71 | 1·65 | 4·88 | 6·51 | 6·44 | 5·55 | 3·37 | 2·06 | ·76 | ·54 | 33·11 | 37 |
| Esperance, Western Australia .. | ·57 | ·67 | ·99 | 1·51 | 2·94 | 4·10 | 3·99 | 3·81 | 2·73 | 2·15 | ·97 | ·84 | 25·27 | 29 |
| Eucla, Western Australia .. | ·66 | ·53 | ·97 | 1·20 | 1·23 | 1·15 | ·90 | ·96 | ·76 | ·68 | ·70 | ·39 | 10·13 | 37 |
| Port Augusta, South Australia .. | ·54 | ·46 | ·75 | ·82 | 1·15 | 1·18 | ·69 | ·86 | ·93 | ·88 | ·69 | ·51 | 9·46 | 53 |
| Adelaide, South Australia .. | ·73 | ·60 | 1·06 | 1·87 | 2·74 | 3·10 | 2·66 | 2·50 | 1·95 | 1·74 | 1·15 | ·94 | 21·04 | 74 |
| Robe, South Australia .. .. | ·80 | ·65 | 1·19 | 1·91 | 3·04 | 4·01 | 3·95 | 3·62 | 2·15 | 1·69 | 1·07 | 1·01 | 24·69 | 52 |
| Albury, New South Wales .. | 1·44 | 1·70 | 2·06 | 2·12 | 2·50 | 3·47 | 2·77 | 2·76 | 2·57 | 2·71 | 1·99 | 1.05 | 27·75 | 49 |
| Launceston, Tasmania .. .. | 2·01 | 1·14 | 1·83 | 2·01 | 2·58 | 3·48 | 2·97 | 2·75 | 2·96 | 2·62 | 1·79 | 2·00 | 28·14 | 26 |

### Comparison of Climatic Regions.

Each of the four or five main divisions of Australia which have been described in the foregoing can be paralleled by simlar regions in other parts of the world. These are briefly summarized in the following table (based on Herbertson and Koepper) :—

| Australian. | Extra-Australian. |
|---|---|
| 1. Summer rain region .. .. | Sudan, Brazil (like the wetter north portion); and South Siberia and Argentine (like the drier south-east portion) |
| 1A. North-east coast (trade wind region) | Florida, South China coast |
| 2. Dry region .. .. .. | Kalahari, Atacama, Sahara, Arizona |
| 3. Uniform rain region .. .. | Uruguay, Cape Colony (south-east) |
| 3A. Autumn maximum .. .. | Eastern U.S.A.,Natal, South-east Brazil |
| 4. Winter rain region .. .. | Cape Colony (west), Chili, California, and Mediterranean lands |

## IX.—CHARACTERISTICS OF DROUGHT YEARS IN AUSTRALIA.

As would naturally be expected, years drier than normal in Australia are, in general, years with air pressure above normal, and *vice versâ*. A comparison of the barometric and rain records for the various capital cities bears this out, though in some cases with only moderate emphasis. For example, Melbourne gives 30 cases in favour of this rule and 24 against it. Sydney, 36 for, 18 against; Brisbane, 20 for to 5 against; Adelaide, 40 for to 15 against; Perth, 28 for, 9 against; and Hobart, 22 for, and 18 against. The probability of this rule holding seems to vary with the latitude, being greater as the tropic is approached. Thus the probability that this will be so, for Hobart is ·55, for Melbourne ·56, for Adelaide ·73, for Sydney ·66, for Perth ·76, and for Brisbane ·80.

Confining attention to the period since 1880, the information for previous years being rather too scanty for any adequate review of their peculiarities, the principal drought years affecting the inland areas of South Australia, Victoria, and New South Wales, were 1881, 1884, 1885, 1888, 1895, 1896, 1897, 1899, 1902, 1907, and 1911. In considering drought years, attention is directed rather to the failure of the rains during the critical periods for grass and crops, which may be taken as extending from 1st April to 31st October. The small annual rain totals for all but one of these constituted them drought years in any case, the exception, and a very remarkable one, being 1911, which, if the total rainfall alone is considered, stands out as one of the wettest years on record for Victoria, owing to two tremendous rainfalls in February and March. From July onward it was extremely dry, as were also the first five months of 1912. The years 1884 and 1885 were not universally bad, the former being very dry only in the eastern States, and the latter in South Australia.

The following tables show for Melbourne and Adelaide the mean pressure and temperature departures from the normal for each month of these years. As may be seen from these, considering the year as a whole, for Melbourne,

8 out of the 11 years are above normal pressure, and a similar proportion below normal temperature. The Adelaide records agree as regards pressure, but disagree altogether as regards temperature, only 4 out of the 11 being years colder than the average.

From a seasonal forecast point of view, the Melbourne temperature figures for the first three months are very interesting, and suggest the possibility of using them to forecast the character of the following nine, no less than 25 out of 33 being below the average. The Adelaide temperatures suggest a similar possibility, though not so strongly, only 20 of them being below and 13 above normal. As regards pressure, Melbourne suggests nothing, but Adelaide shows 23 above to 10 below normal for the first three months.

Similar data for Alice Springs show that, as at Adelaide, pressure and temperature are generally above normal for the drought years as a whole.

### Drought Years.

*Melbourne—Mean Air Pressure Departures from Normal.*

| Year. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1881 .. | + ·00 | + ·05 | + ·04 | + ·07 | − ·02 | − ·06 | + ·16 | + ·09 | + ·04 | + ·07 | − ·08 | − ·04 | + ·030 |
| 1884 .. | − ·05 | + ·02 | + ·06 | + ·05 | + ·04 | − ·02 | + ·15 | − ·08 | + ·00 | + ·01 | + ·05 | − ·15 | + ·008 |
| 1885 .. | + ·06 | − ·04 | − ·04 | + ·13 | + ·05 | + ·05 | + ·13 | − ·08 | + ·08 | + ·17 | + ·08 | + ·12 | + ·060 |
| 1888 .. | + ·01 | + ·03 | + ·01 | + ·16 | + ·07 | + ·00 | − ·08 | + ·07 | + ·16 | + ·16 | + ·02 | + ·05 | + ·056 |
| 1895 .. | + ·03 | − ·00 | + ·09 | − ·01 | + ·08 | + ·00 | − ·11 | − ·12 | − ·09 | + ·03 | + ·09 | − ·11 | − ·008 |
| 1896 .. | − ·01 | + ·05 | − ·02 | − ·11 | + ·03 | − ·02 | − ·14 | + ·02 | + ·11 | + ·08 | + ·09 | + ·06 | + ·012 |
| 1897 .. | − ·03 | + ·01 | − ·01 | − ·03 | + ·00 | + ·15 | − ·00 | − ·02 | − ·01 | − ·10 | − ·03 | + ·08 | + ·003 |
| 1899 .. | − ·13 | + ·03 | − ·06 | − ·04 | − ·01 | − ·03 | + ·15 | + ·13 | + ·11 | + ·07 | − ·11 | + ·04 | + ·014 |
| 1902 .. | − ·09 | − ·03 | − ·01 | + ·06 | + ·11 | + ·07 | + ·10 | + ·19 | − ·03 | + ·04 | + ·02 | − ·05 | + ·035 |
| 1907 .. | − ·02 | + ·06 | − ·03 | − ·12 | + ·10 | + ·11 | − ·07 | − ·18 | − ·04 | − ·04 | − ·02 | − ·03 | − ·021 |
| 1911 .. | + ·08 | − ·06 | − ·04 | − ·09 | − ·03 | + ·01 | − ·00 | + ·08 | − ·00 | + ·09 | + ·00 | − ·14 | − ·005 |

### Drought Years.

*Melbourne—Temperature Departures from Normal.*

| Year. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1881 .. | + 0·2 | − 1·2 | + 0·3 | − 0·6 | + 2·1 | − 2·5 | + 0·8 | + 0·9 | + 0·2 | − 1·4 | − 0·9 | − 1·4 | − 0·1 |
| 1884 .. | − 3·3 | − 2·2 | − 0·2 | + 0·4 | − 0·8 | + 0·5 | − 1·2 | + 2·3 | + 1·0 | − 1·8 | − 0·6 | − 2·1 | − 0·5 |
| 1885 .. | − 1·9 | − 1·9 | − 2·0 | − 1·4 | + 1·1 | − 1·6 | − 1·5 | + 1·7 | + 0·2 | + 0·6 | − 0·7 | + 1·4 | − 0·6 |
| 1888 .. | − 2·2 | − 0·9 | − 4·1 | − 1·0 | + 0·1 | + 1·7 | − 0·1 | − 2·6 | + 0·2 | − 1·7 | + 1·9 | + 2·8 | − 0·5 |
| 1895 .. | − 0·6 | + 3·0 | − 0·5 | + 1·0 | − 1·4 | − 0·4 | − 1·3 | + 2·2 | + 0·1 | + 3·1 | − 0·1 | + 1·6 | + 0·6 |
| 1896 .. | + 1·2 | − 0·4 | − 1·8 | − 0·8 | − 0·7 | − 1·1 | − 0·4 | − 1·5 | − 1·2 | + 0·4 | + 1·8 | + 2·7 | − 0·1 |
| 1897 .. | − 2·3 | − 1·4 | − 4·0 | − 1·2 | − 2·1 | + 0·8 | + 2·0 | − 2·1 | + 1·1 | − 1·4 | + 2·3 | + 4·3 | − 0·3 |
| 1899 .. | − 3·6 | + 3·2 | + 2·9 | + 0·6 | − 1·3 | − 1·0 | − 1·5 | − 0·3 | + 1·8 | − 2·0 | − 0·1 | + 2·7 | + 0·2 |
| 1902 .. | − 0·8 | − 2·4 | − 2·2 | − 0·7 | + 0·9 | − 1·3 | + 0·8 | − 3·1 | − 0·4 | + 0·4 | + 4·1 | + 1·0 | − 0·3 |
| 1907 .. | − 0·9 | − 2·6 | − 2·6 | − 1·5 | − 1·3 | − 2·1 | − 0·5 | + 1·6 | + 1·8 | + 0·6 | + 2·9 | − 1·4 | − 0·2 |
| 1911 .. | + 0·3 | + 1·1 | − 0·3 | − 2·4 | + 1·2 | − 1·7 | − 1·0 | + 3·2 | + 1·6 | − 0·5 | + 2·1 | − 1·0 | + 0·3 |

DROUGHT YEARS.

*Adelaide—Mean Air Pressure Departures from Normal.*

| Year. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1881 .. | − ·03 | + ·07 | + ·09 | + ·08 | − ·01 | + ·01 | + ·18 | + ·09 | + ·04 | + ·08 | − ·03 | − ·015 | + ·046 |
| 1884 .. | + ·02 | + ·01 | + ·03 | + ·04 | + ·035 | − ·05 | + ·17 | − ·06 | + ·00 | + ·03 | + ·04 | − ·10 | + ·014 |
| 1885 .. | + ·06 | − ·00 | + ·01 | + ·09 | + ·04 | + ·11 | + ·10 | − ·07 | + ·08 | + ·12 | + ·02 | + ·065 | + ·060 |
| 1888 .. | − ·01 | + ·03 | + ·07 | + ·11 | + ·05 | + ·03 | − ·04 | + ·05 | + ·13 | + ·16 | + ·01 | + ·025 | + ·051 |
| 1895 .. | − ·005 | + ·01 | + ·12 | − ·02 | + ·12 | + ·05 | − ·09 | − ·095 | − ·075 | + ·05 | + ·115 | − ·06 | + ·009 |
| 1896 .. | + ·00 | + ·015 | − ·03 | − ·09 | + ·06 | + ·01 | − ·11 | + ·06 | + ·12 | + ·06 | + ·05 | + ·06 | + ·018 |
| 1897 .. | + ·03 | + ·01 | + ·04 | − ·00 | + ·03 | + ·08 | + ·03 | − ·01 | − ·00 | − ·07 | + ·01 | + ·03 | + ·015 |
| 1899 .. | − ·02 | + ·01 | − ·05 | − ·05 | + ·03 | − ·01 | + ·13 | + ·11 | + ·09 | + ·06 | − ·08 | + ·06 | + ·023 |
| 1902 .. | − ·06 | + ·01 | + ·03 | + ·06 | + ·10 | + ·07 | + ·07 | + ·175 | − ·01 | − ·00 | + ·015 | − ·05 | + ·033 |
| 1907 .. | − ·005 | + ·05 | + ·01 | − ·06 | + ·10 | + ·05 | − ·07 | − ·17 | − ·015 | − ·03 | − ·03 | − ·01 | − ·015 |
| 1911 .. | + ·03 | − ·045 | + ·01 | − ·06 | − ·005 | + ·07 | − ·03 | + ·01 | − ·02 | + ·10 | − ·01 | − ·08 | − ·001 |

DROUGHT YEARS.

*Adelaide—Mean Temperature Departures from Normal.*

| Year. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1881 .. | − 0·4 | − 3·0 | + 0·6 | − 0·7 | + 1·1 | − 2·4 | − 0·5 | − 0·5 | + 0·1 | − 2·4 | − 1·6 | − 0·7 | − 0·8 |
| 1884 .. | − 4·0 | + 0·4 | + 1·9 | + 1·2 | − 0·6 | + 0·6 | − 1·9 | + 2·2 | + 0·4 | − 2·0 | − 1·0 | − 4·0 | − 0·7 |
| 1885 .. | − 3·4 | − 3·2 | − 3·3 | − 1·0 | + 3·0 | − 1·9 | − 0·3 | + 1·3 | + 0·2 | + 2·5 | − 0·5 | + 2·7 | − 0·3 |
| 1888 .. | + 0·6 | − 3·0 | − 2·2 | + 2·2 | + 0·3 | + 1·6 | + 1·0 | − 1·7 | + 2·7 | + 0·9 | + 4·4 | + 3·7 | + 0·9 |
| 1895 .. | − 0·3 | + 1·8 | − 0·3 | − 0·4 | − 2·1 | + 0·4 | − 0·8 | + 1·6 | + 0·2 | + 3·7 | − 0·1 | − 0·3 | + 0·3 |
| 1896 .. | + 0·7 | + 1·0 | + 2·3 | − 0·3 | − 1·2 | − 2·1 | − 1·1 | − 1·1 | − 0·4 | + 3·0 | + 4·2 | + 0·3 | + 0·5 |
| 1897 .. | − 3·4 | + 1·4 | − 2·6 | + 0·4 | − 0·9 | + 0·6 | + 1·7 | − 1·2 | + 0·8 | − 1·5 | + 2·6 | + 6·3 | + 0·4 |
| 1899 .. | − 7·2 | + 4·5 | + 2·2 | + 0·8 | − 1·0 | − 0·0 | − 2·5 | 0·0 | + 0·9 | − 0·3 | 0·0 | + 0·9 | − 0·1 |
| 1902 .. | − 1·4 | − 3·0 | − 2·9 | + 1·9 | + 3·5 | + 0·2 | + 1·4 | − 0·8 | + 1·3 | + 2·1 | + 4·6 | − 1·6 | + 1·5 |
| 1907 .. | − 3·4 | + 2·0 | − 4·7 | − 2·8 | + 0·7 | − 1·2 | + 0·3 | + 1·0 | + 3·0 | − 0·1 | + 1·2 | − 3·0 | + 0·4 |
| 1911 .. | + 0·6 | − 3·0 | − 2·0 | − 1·7 | + 0·3 | − 0·5 | + 0·7 | + 2·7 | + 0·8 | − 1·1 | + 5·0 | − 2·8 | + 1·0 |

## Drought Years.

*Alice Springs—Mean Air Pressure Departures from Normal.*

| Year. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1881 .. | − ·05 | − ·00 | + ·03 | − ·00 | − ·07 | + ·01 | + ·08 | + ·06 | + ·04 | + ·00 | − ·05 | − ·00 | + ·003 |
| 1884 .. | + ·05 | − ·01 | − ·03 | + ·01 | + ·02 | − ·02 | + ·06 | − ·06 | − ·02 | + ·03 | − ·00 | − ·03 | − ·001 |
| 1885 .. | + ·01 | + ·03 | + ·04 | + ·07 | − ·00 | + ·10 | + ·02 | − ·01 | + ·03 | + ·08 | + ·08 | + ·02 | + ·042 |
| 1888 .. | − ·05 | + ·01 | + ·08 | + ·04 | + ·02 | + ·04 | + ·02 | + ·02 | + ·09 | + ·10 | + ·02 | + ·03 | + ·036 |
| 1895 .. | − ·01 | + ·00 | + ·08 | − ·02 | + ·06 | + ·04 | + ·00 | + ·00 | − ·06 | + ·02 | + ·07 | − ·03 | + ·014 |
| 1896 .. | − ·02 | − ·04 | − ·07 | − ·03 | + ·06 | − ·01 | − ·08 | + ·07 | + ·09 | − ·00 | + ·02 | + ·01 | − ·001 |
| 1897 .. | + ·06 | + ·03 | + ·05 | + ·00 | + ·03 | − ·02 | + ·04 | + ·01 | + ·00 | − ·08 | + ·00 | − ·02 | + ·010 |
| 1899 .. | + ·02 | + ·01 | − ·02 | − ·05 | + ·00 | − ·01 | + ·02 | + ·05 | + ·03 | + ·03 | − ·03 | + ·05 | + ·009 |
| 1902 .. | − ·05 | + ·02 | + ·02 | + ·03 | + ·05 | + ·06 | + ·03 | + ·08 | − ·01 | + ·01 | + ·03 | + ·02 | + ·026 |
| 1907 .. | − ·04 | + ·04 | − ·01 | − ·00 | + ·03 | − ·02 | − ·06 | − ·04 | + ·02 | − ·04 | + ·03 | − ·02 | − ·009 |
| 1911 .. | − ·03 | − ·02 | + ·01 | − ·06 | − ·03 | + ·05 | − ·06 | − ·03 | − ·02 | + ·04 | − ·02 | + ·00 | − ·015 |

## Drought Years.

*Alice Springs—Mean Temperature Departures from Normal.*

| Year. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1881 .. | + 3·7 | + 0·7 | − 0·4 | + 3·4 | + 7·4 | − 1·1 | − 0·4 | + 1·5 | − 1·0 | + 0·6 | + 1·7 | + 1·7 | + 1·5 |
| 1884 .. | + 2·1 | + 3·7 | + 3·3 | + 0·7 | − 2·3 | + 2·1 | − 1·8 | + 4·9 | + 2·8 | − 1·1 | + 0·1 | − 0·5 | + 1·2 |
| 1885 .. | + 0·4 | + 0·7 | − 6·1 | − 4·1 | + 4·9 | − 3·7 | − 0·7 | + 2·3 | + 3·2 | + 3·1 | − 0·3 | + 2·0 | + 0·1 |
| 1888 .. | + 5·0 | + 1·1 | − 2·3 | + 4·1 | − 0·1 | + 1·5 | − 0·3 | + 1·8 | − 1·8 | − 1·4 | + 3·8 | + 4·2 | + 1·3 |
| 1895 .. | − 7·0 | − 3·7 | − 1·3 | − 0·1 | − 2·1 | − 0·3 | − 2·6 | − 1·5 | − 0·4 | − 2·1 | − 2·7 | + 2·7 | − 1·7 |
| 1896 .. | + 1·8 | + 0·3 | + 4·9 | + 2·5 | − 1·5 | − 2·7 | + 0·4 | − 5·5 | − 3·3 | + 4·5 | − 0·2 | + 5·8 | + 0·6 |
| 1897 .. | + 0·6 | − 0·3 | − 0·3 | + 1·7 | − 1·0 | + 2·9 | + 1·6 | − 0·1 | + 0·0 | + 4·5 | + 1·7 | + 0·8 | + 1·0 |
| 1899 .. | − 6·4 | + 1·5 | + 0·9 | + 2·1 | − 1·9 | + 0·3 | − 3·7 | − 2·6 | + 2·4 | − 0·8 | + 1·9 | + 0·3 | + 1·0 |
| 1902 .. | + 3·6 | + 3·0 | + 0·3 | − 0·7 | − 0·1 | − 0·6 | + 2·2 | − 2·3 | + 2·8 | + 1·9 | − 0·4 | + 0·3 | − 0·5 |
| 1907 .. | − 1·6 | − 1·9 | − 0·5 | − 1·9 | − 1·4 | − 0·5 | + 3·0 | + 0·5 | − 1·8 | + 2·5 | − 4·5 | − 2·5 | + 0·5 |
| 1911 .. | − 0·5 | − 1·9 | − 2·1 | + 1·1 | + 2·1 | − 1·0 | + 2·3 | + 1·7 | − 0·6 | + 1·0 | + 0·8 | − 1·0 | − 0·7 |

As the years 1888 and 1902 stand out beyond all others as drought years, a comparison between the two may be instructive. It is worth noting, to begin with, that the former was sandwiched between years of excessive rainfall, but that the latter was the culmination of a long stretch of years with low average rainfall which began in 1895. The year 1888 was characterized by extreme simplicity in weather types, there being scarcely any departure from the normal type. Pressures were higher than normal throughout the year in Melbourne and Adelaide, except in July, and expecially so in the Spring months. The low pressure systems were almost entirely of " Antarctic " type, there being few inland rains of tropical origin, even in summer, and during the seven winter months—April to October—practically no rains due to tropical incursions of low pressure systems. Cyclonic developments from " Antarctic " low pressures were absolutely wanting during the whole year, the tendency being towards a succession of high-pressure systems on the mainland, and low-pressure systems with centres far to southward passing along the south coast line. For the year as a whole, the departures from the average mean pressure were very large throughout Australia, averaging four-hundredths of an inch in excess at the six capital cities.

The year 1902 was also marked by pressures much above normal, but in other respects differed very strikingly from 1888. In 1888, the depressions followed one another over the southern waters with but little hindrance and without making many inroads upon the high-pressure systems upon their equatorial sides; in 1902, at all events during the five critical months, April to August, high-pressure systems were continually being built up over Tasmania and South-eastern Australia, apparently through the agency of large cyclonic depressions operating over Tasman Sea or New Zealand, many of which were of tropical origin. The result upon storm systems approaching from the west was generally disastrous; some were deflected too far south to affect Eastern Australia; some seemed to die out before arrival, and some were converted into feeble cyclonic circulations, which had little rain-producing effect. The last two months in both years were, however, a good deal alike, in that depressions of tropical origin became frequent; possibly owing to the approach of improved conditions.

The pressure excesses at the different capitals for the years 1902 were almost as large as in 1888, and bear out to some extent the tendency for high-pressure systems to form over Tasmania.

This would suggest two main dry weather types:—

(*a*) High and low-pressure belts maintaining their respective latitudes, with little tendency to departure from normal position—probably the result of a general lack of humidity in the atmosphere. Of this, 1888 is most typical.

(*b*) Unfavorable location of high-pressure systems over South-Eastern Australia and Tasmania, co-incident with the operation of great storm systems over Tasman Sea and New Zealand, and a tendency to the formation of slow-moving feeble cyclonic circulations advancing from the westward. This was most characteristic of 1902.

Examination of the weather charts of other drought years shows that they partake more or less of the characteristics just defined. For example, the winter months of 1899, showed a very decided tendency to the pressure distribution of 1902, though tropical cyclonic storm systems off the east coast of New South Wales were much more pronounced, with the result that the coastal rains there were well above the average for that year; 1895 resembled 1888, but the "Antarctics" were stronger; 1896 favoured the 1902 type, but the tendency to cyclonic development was much greater; 1897 also tended to resemble 1902, but with occasional departures to the other type. The years 1907 and 1911 do not show any special likeness to any drought years, and seem to have been dry from various causes; 1907 can hardly be taken as a typical drought year, inasmuch as the truly drought conditions were limited to the eastern States in area, and to the spring months in time. The great deficiency was in September and October, the previous shortage not being very serious. A study of the Weather Charts for these two months reveals two tendencies, one of which, at all events, tends to relate their pressure distribution to that of 1888, the southern circulation being of pronounced westerly type. This is shown by a decided tendency to flattened "Λ" depressions, so that winds in front of a storm would be more from north-west than north-east and in rear from west than south. This was probably due to exceptional rapidity of eastward storm movement, n higher latitudes, an idea suggested by the frequency with which monsoonal troughs in connexion with Antarctic storms were given a north-west to south-east lie. The charts of 18th and 19th October are typical of these conditions, and are distinct dry spring types. These show a high-pressure system pressing eastward over the head of the bight. This is a very unfavorable sign for rain over southern parts, as it has the apparent effect of cutting off trough connexion with the tropical low-pressure belt, and, in addition, means the establishment of anticyclonic conditions over south coastal areas. It is characterized by persistent westerly winds over southern waters. The spring of 1909 is another good example of this tendency and was similarly dry. The type exemplified in Figures 66 and 67 may be regarded as a special one characteristic of dry weather in spring, as it most frequently occurs between August and December.

Another special type, which does not seem inconsistent with a moderately humid condition of the atmosphere and yet often causes prolonged dry spells over the inland portions of South-eastern Australia, is that already mentioned as of frequent occurrence in 1899. Here high pressures tend to centre over Tasmania, or to form an elongated system extending from Southern New Zealand to Tasmania, and thence towards Central Australia. The apparent cause of this arrangement practically always seems to be a cyclonic storm, usually of tropical origin, located on its northern side, and often off the New South Wales coast line, along which the rainfall is generally very heavy owing to the upthrust given by seaward slopes to the strong south-easterly winds in the south-west quadrant of the cyclone. Inland areas do not benefit appreciably, and as these systems tend to persist for several days at a time, and seem not only to prevent the advance of rain-bearing storms from the west, but to destroy their energy, the occurrence of a number of them during the rainy season may have a very appreciable effect in lessening the inland rainfall. See charts for 12th August, 1899, and 28th September,

ISOBARIC CHARTS CHARACTERISTIC OF DROUGHT YEARS.

| TYPE (a) | TYPE (b) |
| --- | --- |

*TYPE (a)*

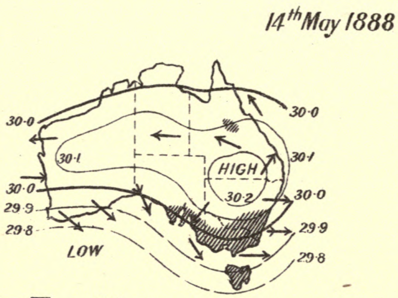



FIG. 60.

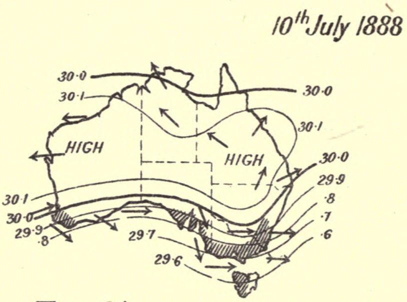



FIG. 61.

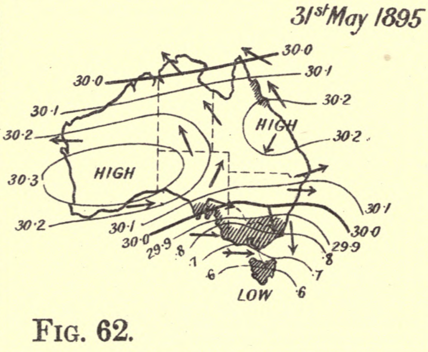



FIG. 62.

*TYPE (b)*

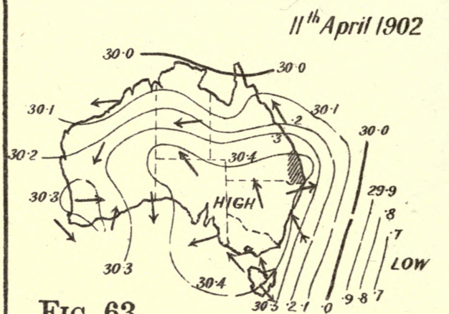



FIG. 63.

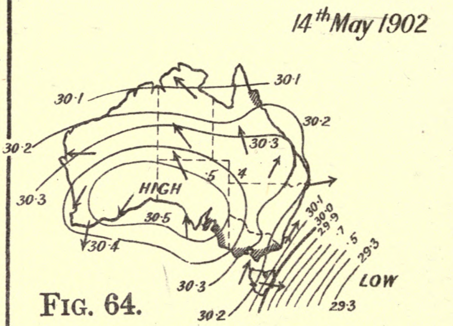



FIG. 64.

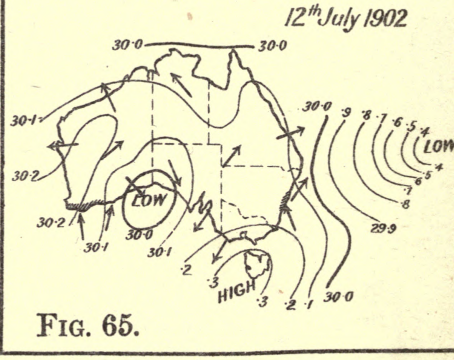



FIG. 65.

NOTE.—Shading shows where rain fell during previous 24 hours.

1909. Figures 68 and 69. The tendency to this distribution was very pronounced during the seven winter months of 1899, and in particular during the months of July and August, when the inland rains were very scanty.

In the following table the years are arranged in two sections—(*a*) and (*b*)—representing the two most distinct drought types, and the barometric departures from the normal for the whole year at the various capital cities are also given to show how far these support the classification. As will be seen, they do this fairly well:—

DEPARTURE FROM NORMAL ANNUAL AIR PRESSURE.

| Year. | Hobart. | Melbourne. | Sydney. | Brisbane. | Adelaide. |
|---|---|---|---|---|---|
| | | *Type (a).* | | | |
| 1888 .. .. | +·029 | +·060 | +·053 | +·039 | +·051 |
| 1895 .. .. | .. | −·004 | +·010 | −·001 | +·009 |
| 1907 .. .. | −·035 | −·017 | +·007 | −·013 | −·015 |
| | | *Type (b).* | | | |
| 1902 .. .. | +·058 | +·029 | +·032 | +·020 | +·033 |
| 1896 .. .. | +·021 | +·016 | +·017 | +·009 | +·018 |
| 1897 .. .. | +·032 | +·007 | +·015 | +·007 | +·015 |
| 1899 .. .. | +·041 | +·020 | +·020 | +·010 | +·023 |
| 1911 .. .. | +·022 | −·009 | −·008 | −·012 | −·001 |

The weather charts, Figures 60-62, illustrate the 1888 type, and Figures 63-65 show some typical of 1902 pressure distribution.

## VARIATION OF THE WINTER RAINFALL OVER NORTHERN VICTORIA WITH MEAN PRESSURE AND PRESSURE RANGES (1887–1911).

A detailed study of the relation between the inland rains over Victoria, the mean air pressure at Melbourne and the extreme pressure ranges as shown during the passage of storm systems over Victoria during each month, gave the following results for the seven months, April–October inclusive. "Agreement" in the case of mean pressure requires departures from normal opposite in sign to those from rainfall, and in the case of pressure ranges the same sign with those for rainfall:—

| — | | April. | May. | June. | July. | August. | September. | October. |
|---|---|---|---|---|---|---|---|---|
| Mean Pressure | Agreement | 12 | 16 | 15 | 16 | 17 | 13 | 12 |
| | Disagreement | 10 | 9 | 7 | 9 | 8 | 11 | 11 |
| Pressure Ranges | Agreement | 12 | 19 | 11 | 18 | 17 | 12 | 11 |
| | Disagreement | 13 | 6 | 14 | 7 | 8 | 13 | 14 |

This shows a certain tendency for the rainfall to vary inversely with the mean monthly pressure, but it is not a very pronounced one for the first and last two months of the series, and seems to be more especially a winter relationship.

The tendency for the rainfall to vary directly with the range of pressure is also evident, but the balance of probability that this will be so is even less than in the preceding case. In May, July, and August large pressure ranges favour increased rainfall; the other months are almost indifferent.

### Variations in Rainfall with Storm Types.

The winter rainfall of Australia, or, at all events, that of its southern portion, occurs in connexion with barometric depressions of various types which may be classified as follows:—(1) Antarctic V-depressions, *i.e.*, storms the centres of which pass too far south to be indicated by closed isobars and which, in many cases, seem to be of such vast extent that they may almost be regarded as portions of the great southern low-pressure belt. If rain-producing inland their northern isobars take the form of inverted "Vs," though some may open out to northward so as to define a barometric trough running well into the interior of the continent, or even connecting with the tropical low-pressure belt. (2) Antarctic cyclones, circulatory systems originating over southern waters and passing from the Bight over South-eastern Australia, or through Bass Straits. (3) Tropical depressions shown isobarically by (*a*) dips southwards from the tropical low-pressure belt into a high-pressure system south of or over southern parts of the continent; (*b*) troughs connecting with and originating in the tropical low-pressure belt; (*c*) cyclonic systems of tropical origin.

Tropical depressions when well developed are much the most productive of good inland rains, and judging by their cloud circulation are caused by southward flows of the atmosphere of wide extent and considerable depth. The first form of depression, however, "Antarctic disturbance," is much the most frequent in winter, and when it is supplemented by trough-development extending well into the northern interior brings much rain to the inland areas of South Australia, Victoria, New South Wales, and even Queensland. But, in general, the absence of cyclonic development indicates a dry season even though the "Antarctics" themselves are of considerable intensity.

In the following table is shown for the several winter months the average rain per storm received over Northern Victoria when (*a*) all the storms are of simple Antarctic type; (*b*) when some of the storms experienced were cyclonic in form or tropical in origin; also the monthly rainfall when (A) all the storms were Antarctic; and (B) when some were cyclonic or of tropical origin. This method of grouping is adopted owing to the impossibility at present of determining the rainfall for each storm separately:—

| — | April. | | May. | | June. | | July. | | August. | | September. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Storms. | Average Rain. | Number of Storms. | Average Rain. | Number of Storms. | Average Rain. | Number of Storms. | Average Rain. | Number of Storms. | Average Rain. | Number of Storms. | Average Rain. |
| | | Pts. | | Pts. | | Pts. | | Pts. | | Pts. | | Pts. |
| (*a*) .. .. | 56 | 19 | 29 | 31 | 35 | 57 | 57 | 38 | 12 | 51 | 31 | 20 |
| (*b*) .. .. | 62 | 43 | 72 | 52 | 71 | 60 | 86 | 34 | 130 | 31 | 132 | 26 |
| | *Average Monthly Rain.* | | | | | | | | | | | |
| (*A*) .. | .. | 83 | .. | 125 | .. | 222 | .. | 156 | .. | 205 | .. | 126 |
| (*B*) .. | .. | 204 | .. | 218 | .. | 264 | .. | 180 | .. | 182 | .. | 174 |

## TENDENCY TO ISOBARIC DISTRIBUTION NOTICEABLE IN DRY SPRINGS.

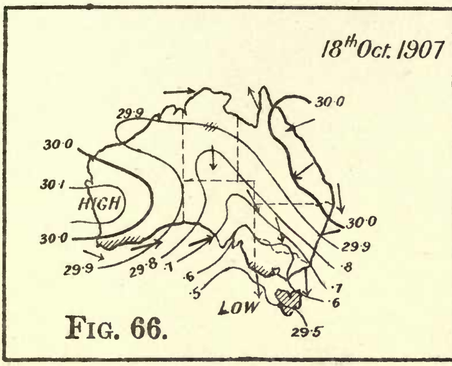



Fig. 66.

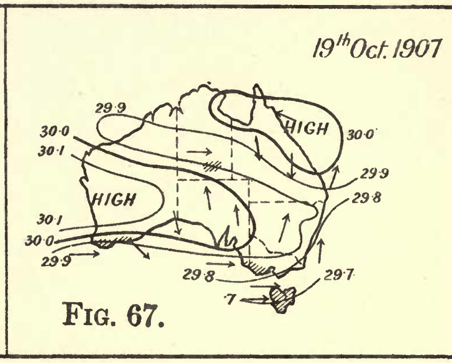



Fig. 67.

## EAST COAST CYCLONES

favouring heavy East Coast Rains, but Dry Spells Inland.

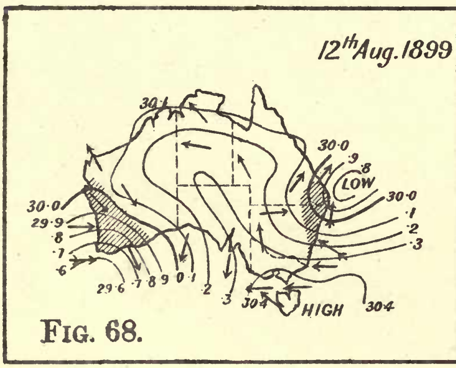



Fig. 68.

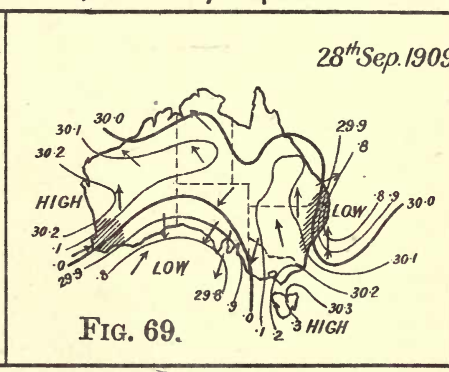



Fig. 69.

## CONTRASTED TYPES

showing increased rain production inland when "Antarctic" is supplemented by Trough connection with Tropical Low Pressures.

(*a*) Wet Chart—Tropical influence pronounced. (*b*) Dry Chart—Tropical influence absent.

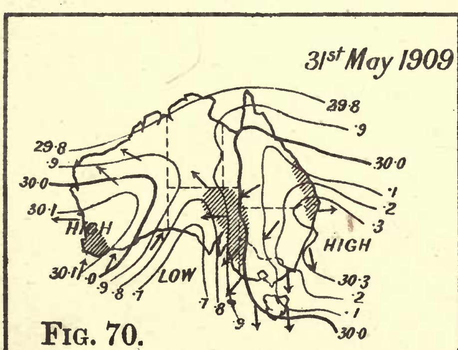



Fig. 70.

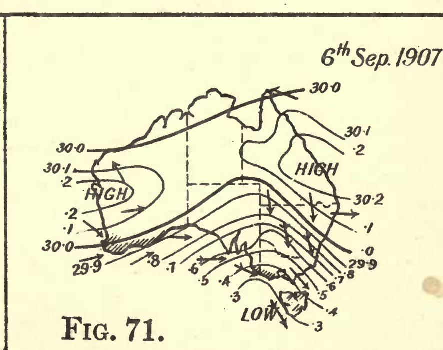
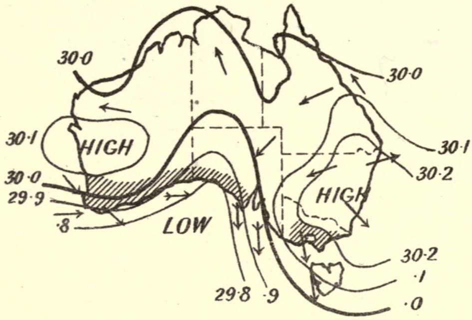



Fig. 71.

Note.—Shading shows where rain fell during previous 24 hours.

FIG. 72.

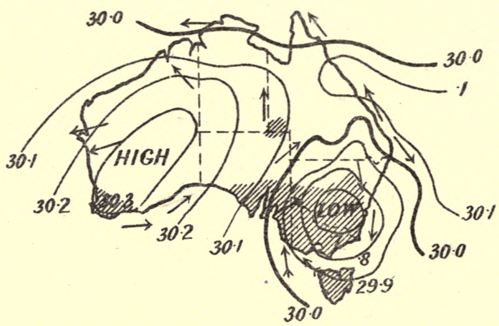
2nd June 1911




(a) ORDINARY ANTARCTIC DEPRESSION.

FIG. 73.

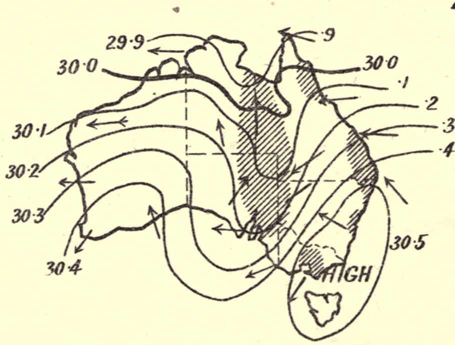
2nd Sep. 1911




(b) CYCLONE—ANTARCTIC ORIGIN.

FIG. 74.

22nd June 1912




(c) TROPICAL DIP.

NOTE.—Shading shows where rain fell during previous 24 hours.

As will be seen from the table, those months in which air circulation departs from the simple Antarctic type are in general the most rainy. August certainly seems to be an exception, but this may be partly explained by the fact that only three months of August, in which all storm systems were "Antarctic," occurred during the 25 years, and also that amongst cyclonic developments are included "tropical troughs" and "dips," which may not always have extended far enough south to appreciably affect Victoria as storm systems. Figures 72-74 show typical specimens of some of the systems above referred to :—

| | |
|---|---|
| Ordinary Antarctic depression .. .. | 2nd June, 1911. |
| Antarctic cyclone .. .. .. | 2nd September, 1911. |
| Tropical dip .. .. .. .. | 22nd June, 1912. |

### Effect of Air Flow from Tropical Belt.

A very common feature of good winters is the formation of trough-like depressions lying north and south and connecting with the tropical low-pressure belt. These cause extensive rains, falling mostly in front of the trough and extending sometimes right across the continent. They occasionally end by producing a strongly cyclonic circulation over South Australia, New South Wales, or Victoria, or all three, and when this happens the tropical influence seems to come to an end with cessation of trough rains and the production only of those due to the cyclonic system itself. A tongue of high pressure usually now presses from the westward along the northern boundary of the cyclone destroying the tropical connexion, and this is followed by the lessening intensity of the cyclone itself as if its main supply of energy had been cut off. This cyclonic formation and later peculiarities of development are most frequently seen when tropical influences only are operative.

To show the closeness of the relations between the winter rainfalls over the southern and south-eastern interior of Australia and the formation of these troughs over Central Australia, the daily weather charts for all the years available have been consulted, and counts made of the number of days during the six winter months (April–September), when the barometer readings at Alice Springs reduced to sea-level have been below 30·0 inches. In some of the cases the depressions would be due to purely tropical intrusions of low pressure, but it was not thought worth while to attempt to eliminate these, more especially as they would favour the production of the trough-like depression above referred to. The table shows that 19 times out of 25 the rule holds that winter rains are above or below normal according as the number of days occupied by trough depressions giving readings below 30·0 inches and passing over Alice Springs is above or below normal. Then the eight selected dry years for which charts are available give, for the number of days thus occupied, a mean only two-thirds as large as that given by the twelve wet years. A typical wet chart is that of 31st May, 1909, in which the tropical trough connexion is a prominent feature, and dry chart that of 6th September, 1907, in which the trough is wanting. See Figures 70 and 71.

It is perhaps necessary to explain here that the term "trough" is used in a special sense. It is customary to use the word "col" when referring to the space separating the isobars defining two "highs." Analogy is drawn from land contour. Two mountain ridges may be joined by a saddle or col, or separated by a valley, along which perhaps a river flows. So in considering the connexion or separation of two barometric high pressure

systems we may have the "highs" contoured by isobars in such a way that the "col" is either distinctly anticyclonic, the wind circulation of the preceding high almost merging into that of the following one, or distinctly convectional and rather forming connexion between the circulations of two low pressure systems than between those of two "highs." It is for the latter type that the word "trough" is here used. In the case of a col, the isobars of the two "highs" are decidedly convex to one another along their common axis; in the case of a trough the rear isobars of the preceding "high" or the front isobars of the following "high", or both, tend to straighten and the convexity is more apparent in the isobars of the adjacent low pressure systems, producing often an hour glass appearance. The chart of 31st May, 1909, shows the straightening of the rear isobars of the preceding high very well. When a marked north and south lie of the isobars is thus produced it almost invariably happens that much cloud is formed over the trough area and rain falls to a considerable extent over inland districts, a result probably partly due to the cooling of the southward flowing mass of the air in the trough front.

The following table gives the results in detail. The rainfall is a mean derived from twenty typical stations, ten in the northern wheat-growing area of South Australia, and ten in Northern Victoria, and refers only to the seven months' period, April–October:—

| Year. | Mean of Rainfalls of North Victoria and Upper and Lower North of South Australia. | Number of Times Alice Springs Barometer below 30.0 inches Gravity not applied. | |
|---|---|---|---|
| | April–October. | April–September. | |
| | Inches. | Periods. | Days. |
| All years.. | 11·79 | .. | .. |
| 1881 | 9·12 | .. | .. |
| 1882 | 11·86 | .. | .. |
| 1883 | 13·20 | .. | .. |
| 1884 | 10·53 | .. | .. |
| 1885 | 9·08 | .. | .. |
| 1886 | 10·22 | | |
| 1887 | 13·46 | 7 | 19 |
| 1888 | 8·23 | 4 | 7 |
| 1889 | 20·14 | 9 | 17 |
| 1890 | 15·59 | 9 | 18 |
| 1891 | 11 72 | 7 | 12 |
| 1892 | 14·25 | 12 | 15 |
| 1893 | 16·07 | 16 | 34 |
| 1894 | 15·03 | 8 | 8 |
| 1895 | 9·79 | 10 | 16 |
| 1896 | 7·75 | 8 | 14 |
| 1897 | 9·64 | 8 | 15 |
| 1898 | 12·07 | 9 | 19 |
| 1909 | 9·30 | 8 | 11 |
| 1900 | 11·22 | 10 | 14 |
| 1901 | 11·01 | 8 | 14 |
| 1902 | 5·86 | 7 | 10 |
| 1903 | 13·46 | 10 | 25 |
| 1904 | 10·42 | 11 | 17 |
| 1905 | 13·65 | 7 | 20 |
| 1906 | 14·29 | 10 | 28 |
| 1907 | 11·23 | 10 | 22 |
| 1908 | 13·86 | 9 | 13 |
| 1909 | 15·67 | 13 | 24 |
| 1910 | 14·51 | 11 | 17 |
| 1911 | 9·14 | 9 | 13 |

As the evaporation statistics might be expected to throw some light on conditions in general during drought years, the following table is appended. That the light is not particularly bright is evident, the result being confused by the fact that the rate of evaporation is dependent upon a number of factors :—

RAINFALL AND EVAPORATION DURING DROUGHT YEARS.

| Year. | Adelaide. | | Alice Springs. | | Melbourne. | | Sydney. | |
|---|---|---|---|---|---|---|---|---|
| | Rain. | Evaporation. | Rain. | Evaporation. | Rain. | Evaporation. | Rain. | Evaporation. |
| 1881 .. .. | 18·02 | 55·97 | 6·42 | .. | 24·08 | 38·66 | 41·09 | 30·69 |
| 1884 .. .. | 18·74 | 54·70 | 5·39 | .. | 25·85 | 31·59 | 44·04 | 34·45 |
| 1885 .. .. | 15·88 | 54·63 | 17·20 | .. | 26·94 | 32·37 | 29·91 | 36·51 |
| 1888 .. .. | 14·55 | 58·06 | 10·06 | .. | 19·42 | 37·92 | 23·01 | 36·33 |
| 1895 .. .. | 21·28 | 52·09 | 14·18 | 84·33 | 17·04 | 41·97 | 31·86 | 35·54 |
| 1896 .. .. | 15·17 | 56·65 | 10·42 | 90·21 | 25·16 | 38·13 | 42·40 | 35·81 |
| 1897 .. .. | 15·42 | 54·55 | 5·69 | 102·54 | 25·85 | 36·66 | 42·52 | 42·56 |
| 1899 .. .. | 18·84 | 55·55 | 6·53 | 100·02 | 28·87 | 38·63 | 55·90 | 38·56 |
| 1902 .. .. | 16·02 | 58·23 | 5·44 | 108·49 | 23·08 | 38·61 | 43·07 | 36·12 |
| 1907 .. .. | 17·78 | 53·33 | 9·81 | 100·66 | 22·26 | 40·61 | 31·32 | 38·95 |
| 1911 .. .. | 15·99 | 48·14 | 7·09 | .. | 36·61 | 38·87 | 50·03 | 37·55 |
| Mean all years .. | 20·62 | 54·44 | 11·09 | 97·10 | 25·60 | 38·38 | 47·99 | 36·92 |
| Drought Means .. | 17·06 | 54·35 | 8·93 | 97·71 | 25·01 | 37·64 | 40·47 | 36·64 |

Evaporation means for the drought years are thus seen to be, in general, slightly below those for all years of record for the coastal stations, and only slightly above for Alice Springs, the one inland station given. The very low evaporation totals for Alice Springs for 1895 and 1896 were coincident with exceptionally heavy summer rains, and were what should be expected when humid conditions intervene at the time when evaporation is normally most rapid. Otherwise the results show the effect of the drier atmosphere of the drought years. At the coastal stations the lower evaporation, as well as the lower summer temperatures already noted, may be explained by assuming that during drought years the greater insolation over the interior produces greater and more frequent indraughts of moist, cool, sea air.

In the foregoing the rainfall statistics most frequently referred to were those obtained from a mean of the rainfalls at ten typical stations in the northern wheat-areas of Victoria, and a similar number from the northern areas of Southern Australia. These are—for Victoria, Swan Hill, Echuca, Yarrawonga, Warracknabeal, Charlton, Bendigo, Shepparton, Dookie, Horsham, and St. Arnaud; and for South Australia, Hawker, Quorn, Port Augusta, Wilmington, Ororoo, Petersburg, Appila, Crystal Brook, Burra, and Auburn.

The mean annual rainfall for the Victorian stations is 17·82 inches, of which 12·33 fall in the seven months April to October. The wettest year since 1880 was the year 1889, when 26 inches fell, and the driest 1902, when the total was only 10·94 inches, of which only 5·11 fell during the critical seven months. For the South Australian stations the mean annual fall

is 15·0 inches, and for the seven winter months, 11·25. The wettest year in this area was also 1889, with 25·35 inches, and the driest 1888, with 9·21 inches, of which 7·93 fell during the growing period. In 1902, the year's total was 10·70 inches, and that for April–October 6·60 inches.

It will thus be seen that even in the worst years the rainfall over the inland areas considered is sufficient when aided by modern agricultural methods to insure at least moderate yields of cereals from extensive inland areas. That an occasional drought is not an wholly unmixed evil is seen in the unusually abundant crops harvested in the first good season, owing probably to an improved condition of the soil. The most serious effects of prolonged drought are the losses of stock, due to an almost entire dependence upon natural grasses. That these are easily preventable will, no doubt, be proved by future experience.

## X(A).—RAINFALL IN THE WEST AUSTRALIAN GOLD-FIELDS.

In the dry region of Western Australia—for the most part with a rainfall of less than 10 inches per year—are three important centres of settlement. In the north is the Pilbara Gold-field, in the centre the Murchison Gold-field, and in the south the Coolgardie Gold-field. Kalgoorlie has a population of over 17,000 inhabitants, while some £112,000,000 have been won by miners from the gold-fields of Western Australia.

A special study of the rainfall of this area is justified by its economic importance and by its interest as a region which has been settled in defiance of physical control.

### Frequency of Rain Storms.

An analysis has been made of the conditions governing the rainfall in the inland portion of Western Australia during the period July, 1909–July, 1912

The rain storms are classified in three groups—

Coolgardie (Southern Gold-field).
Peak Hill (Central Gold-field).
Pilbara (North-west Gold-field).

In most cases Coolgardie participated in rains from the north which affected the other two, but the contrary is by no means true—rains moving from the south rarely reaching Peak Hill and never Pilbara.

The number of rain storms affecting the fields in this period is shown in the following table (for three years) :—

| — | Summer. December, January, February. | Autumn. March, April, May. | Winter. June, July, August. | Spring. September, October, November. | Total. |
|---|---|---|---|---|---|
| Pilbara .. .. | 10 | 9 | 7 | 1 | 27 |
| Peak Hill .. .. | 13 | 9 | 18 | 8 | 48 |
| Coolgardie .. .. | 12 | 17 | 35 | 18 | 82 |
| Individual Storms* .. | 21 | 24 | 39 | 26 | .. |

* N.B.—Many of these "Individual Storms" affected two centres.

The table shows that Coolgardie lies in the winter rain region, and that Peak Hill gets its infrequent rains both in winter and summer, while Pilbara, so far as frequency is concerned, has a slight summer maximum and a more characteristic spring minimum.

### Direction of Rain Winds.

The wind directions tabulated refer to the dominant winds over the whole rain area ("smear" is used for such local rain) due to one particular storm or set of controls.

The rain winds affecting the dry interior are chiefly from the north to north-east octant, veering to the north-west in part in the colder months. But the south-west and south winds also exercise a beneficial effect, especially in the colder months:—

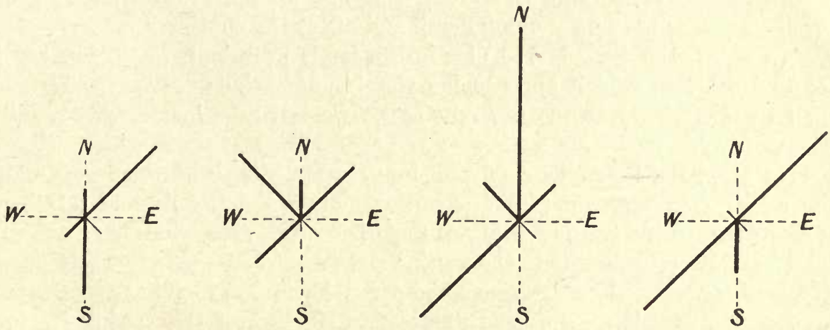



Fig. 75.

| Summer. | Autumn. | Winter. | Spring. |
|---|---|---|---|
| N.E. = 8 } 10 | N.W. = 7 } 16 | N. = 15 } 23 | N.E. = 10 |
| N. = 2 | N. = 3 | N.W. = 4 | S.W. = 10 } 14 |
| | N E. = 6 | N.E. = 4 | S. = 4 |
| S. = 6 } 8 | | | |
| S.W. = 2 | S.W. = 5 | S.W. = 11 | |
| Others 3 | Others 3 | Others 4 | Others 3 |

### Pressure Systems and their Distribution.

The conditions leading to the fall of rain in the interior of Western Australia are by no means always of the same type. The most striking feature shown by the analysis is the persistence of one type throughout a season in one year which may not occur in the same season next year. For instance, in January and February, 1911, there was a greater distance between the low (over Condon) and the high to the south-east (south of Mt. Gambier, &c.) than usual. In June and July, 1910, and 1912, the high covered most of Eastern Australia, while the low off Albany led to rains over the goldfields. In these two months during the intermediate year 1911, there seemed a tendency for the succeeding high to appear sooner off North-west Cape and control the situation. The same "habit" is shown in other months, but not to the extent of obliterating the characteristic features of the distribution of highs and lows each month.

There is perhaps no need to emphasize the fact that, in an immense area like Australia, each climatological division exhibits as diverse features as does, for instance, the whole of the British Isles.

*In January,* the rain *smears* extend usually over the three gold-fields. They occur nearly always when a low lies off North-west Cape—the high being to the south-east, either over the Bight or further east. The wind is generally from the north-east, but if the southern high is rather to the west then south winds also bring rain to the fields.

*In February,* the conditions are much the same. The rains in the north (Pilbara) usually accompany north winds in front of the low, and those in the south south or south-east winds in front of the high. There is a strong tendency for the low to " sit " over the north of the high in this month, when rain is probable.

*In March.*—The above conditions obtain also in March, but in addition rains with south winds occur sometimes with a low south of the Leeuwin and a high advancing on Geraldton (*vide* 2nd March, 1912). The *southern* cyclonic eddies are now moving north and affect the continent.

*In April,* the second type of rain-bringer is prevalent, *i.e.*, a low south of Leeuwin and a high approaching Geraldton. Winds are northerly first, and then southerly as the low advances. Coolgardie rains are due usually to the latter winds.

*In May,* the favorable condition for rain appears to be when two highs lie rather near together (" A " over South-eastern Australia and " B " off Geraldton), with a low just south of Cape Leeuwin. The winds are northerly and the rain smear chiefly in the south.

*In June,* conditions are much the same. The first high lies over Central and East Australia, the second approaches North-west Cape, while the low lies off Cape Leeuwin. The accompanying winds (north-east and then south-west) both lead to rains, though in this month the southern winds affecting Coolgardie region are of increasing importance.

Variation in the position of the preceding high does not seem to be of such importance as gradient. For instance, in June, 1912, the gold-fields experienced a dry spell, although the conditions as stated above recurred about once a week as usual :—

*June,* 1912.

| Date. | Rain. | Highs—Velocity. | Gradient. | Path. |
|---|---|---|---|---|
| 3rd | No rain on fields. but in south-west | 300 (1,200 m. in 4 days) | Gradient small = 28 ($\frac{4}{10}$ in 700 m.) | Centre moved E. from Adelaide to Sydney |
| 10th | Rain over Coolgardie | 450 (900 m. in 2 days) | ($\frac{4}{10}$ in 500 m. Gradient = 40 | Centre moved due E. to Grafton |
| 17th | No rain on fields. Rain in S.W. corner only | 450 (900 m. in 2 days) | Gradient = 33 ($\frac{4}{10}$ in 600 m. but rapidly lessening | Centre moved S.E. Coolgardie to Robe |
| 28th | Rain over Coolgardie | 350 (350 m. in 1 day) | ($\frac{5}{10}$ in 400 m.) = 62 | Centre moved S.E. from Adelaide to Bass Straits |

This summary shows that increased gradient (implying stronger winds) is apparently the most favorable factor in supplying Coolgardie with rain; for the velocity and path varied without effect.

*In July*, the lows are slightly further north than in June, and the preceding high covers Central and Eastern Australia. The winds are usually from the north drawn into the front of the low. Rains due to south-west winds in the rear of the low are also common, especially in the south-west corner.

*In August.*—In 1909 and 1910 the rains were generally due to northerly winds in front of a low. In 1911, they were nearly all due to south-west winds from the rear of the low, the high following close after. The lows appeared to have a somewhat more southern " habit " throughout the month of August in 1911.

*In September*, a tendency for the low to run up between the two highs is noticeable. If the latter are close together so that the gradient is steep there would seem to be better chances for rain. Thus in 1911 in this month there were six high-pressure systems in evidence, but only three with somewhat steeper gradients led to rain.

*In October*, rains are rare in the gold-fields region, and there seems to be no very favorable arrangement of the pressure conditions. Both south-west and north-east winds bring rain, chiefly to the south. Thunderstorms may occur over the fields.

*In November*, a low usually " broods " over Central Australia, sometimes forming a true " monsoonal " tongue from the north. Conditions are very unfavorable for rain over the gold-fields. Thunderstorms may, however, occur and give local rain.

*In December*, the same conditions obtain as in November. Thunderstorms are not uncommon.

Summary of Position of Eddies from July, 1909, to July, 1912.

| — | Highs. | | | | Lows. | | | |
|---|---|---|---|---|---|---|---|---|
| | Summer. | Autumn. | Winter. | Spring. | Summer. | Autumn. | Winter. | Spring. |
| Off Perth and Cape Leeuwin .. | 9 | 8 | 9 | 6 | 1 | 5 | 15 | 1 |
| S. of Esperance and in Bight .. | 6 | 3 | .. | 5 | .. | 12 | 16 | 8 |
| Off N.W. Cape and Cossack .. | 2 | 5 | 5 | 7 | 13 | 1 | .. | 4 |
| Over E. Australia .. .. | .. | 5 | 19 | 9 | .. | .. | .. | .. |
| Others .. .. .. | 2 | 1 | 3 | .. | 1 | 2 | 3 | 7 tongues |

Average figures for the monthly rainfall in the gold-fields have already been given in a preceding section.

## X.(b).—FLOOD RAINS IN AUSTRALIA.

These phenomena occur at infrequent intervals in various regions of the continent, causing considerable damage to stock, bridges, roads, &c., in our sparsely-populated and pastoral territories. Brief summaries of the meteorological conditions accompanying the following occurrences will be of interest:—

(1) 1909, August, floods in South-Eastern Australia.
(2) 1910, January, floods on the Darling.
(3) The heavy rains of Queensland.
(4) The heavy rains of Northern West Australia.

### (1) The Cyclonic Storm of 16th–21st August, 1909 (South-East Australia).*

During the month of August every station in South-Eastern Australia recorded above the normal fall, except the coastal fringe from the Gippsland Lakes northward. In South Australia, where the mean fall in the settled districts ranged up to more than double the normal, and in Victoria, where the greater part of the State had over twice the normal amount, this month will rank as one of the wettest on record.

The rains were not only abnormally heavy, but well distributed through the month, though the rain producing storm systems were actually few in number (only four). They moved slowly, developed well inland, and the path followed by their centres was further north than usual, all passing over or very little south of Tasmania. Each of these disturbances was marked by cold, wet, and stormy weather, but the storm tendencies of the month culminated on the 19th in torrential rains and fierce thunderstorms, which caused one of the most disastrous floods Victoria has ever experienced.

The graphs appended to this book include a series of the 9 a.m. weather charts (see Figs. 77–82) during the passage of an extensive storm system of cyclonic energy which traversed the whole of sub-tropical Australia, from Cape Leeuwin to Gabo, between the 16th and 21st of the month, and was the main factor in the development of the exceptional storm rains and floods now under review. Moving over an area already saturated by a period of almost constant rain—for scarcely a day passed during the previous fortnight without widespread and at times heavy downpours, especially in southern and South-Eastern Australia—its effect was most disastrous, and creeks and rivers, already swollen, were turned into raging torrents which overflowed their banks, and spread ruin and desolation over the surrounding country. The map of the 16th shows the advent of the disturbance, which had rapidly advanced from the southern Indian Ocean during the previous 24 hours, in the extreme west of the continent. Its centre was then off the south-west coast of Western Australia, the embracing isobars being somewhat irregular in shape and gradients moderate, and its rain area covered the whole of that State south from the tropic, with heavy falls near the coast (Perth, 213 points ; and 23 other stations from 1 to 2 inches). Next morning (17th) the centre occupied much the same position, the gradients had lessened and the isobars indicated the tendencies to form a doubleheaded depression, and another general, though less heavy, rain was registered south from the latitude of Geraldton.

On the 18th the gradient had still further declined, but the low area had assumed a definite "$\Lambda$" shape, with its apex intruding well inland to much lower latitudes than on the previous day. This carried the rain, which was again general, on to the tropic, though the area of greatest precipitation was still in the south-west (Perth, 141 ; and nine others over 1 inch). The chart of the 19th shows that the storm area had made a distinct surge eastward to the South Australian coast, with an extension of its isobars into still lower latitudes, and a general intensification and steepening of the gradients. A new high-pressure area of considerable energy had developed over Western Australia, which stimulated the circulation in the rear of the disturbance, while the stationary anticyclone on the east coast and the Tasman Sea maintained velocities in the advancing side. Very disturbed

* Bulletin No. 3—Commonwealth Bureau of Meteorology.

## FLOOD RAINS IN SOUTH-EAST AUSTRALIA.

**Note.**—The parts coloured dark blue represent rivers and districts more or less flooded—the lower portions during August, 1909, the upper portions during January, 1910. Light blue shade indicates over 5″ of rainfall in August, 1909.


Fig. 76.

# Flood Rains

Rain Areas Hatched

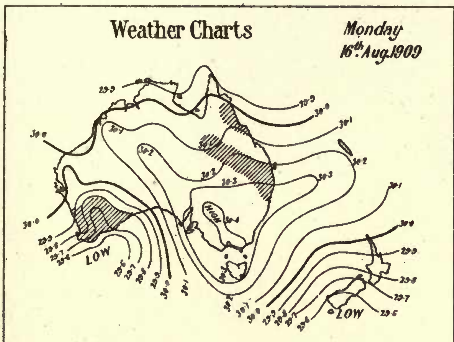



Fig. 77.

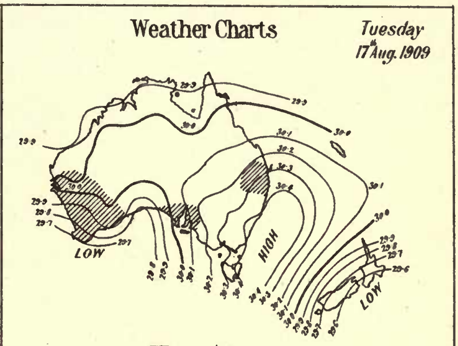



Fig. 78.

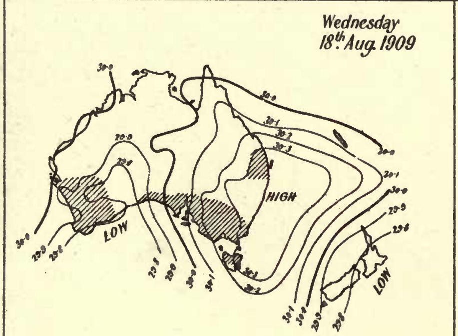



Fig. 79.

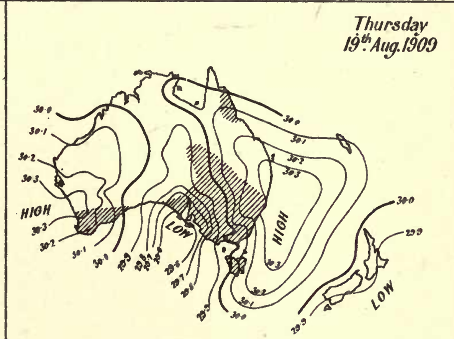



Fig. 80.

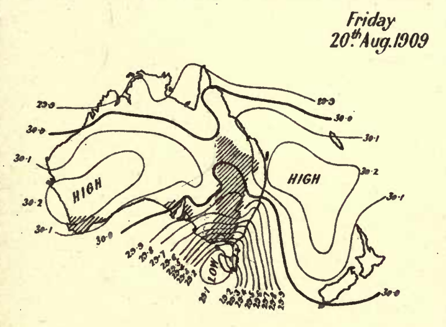



Fig. 81.

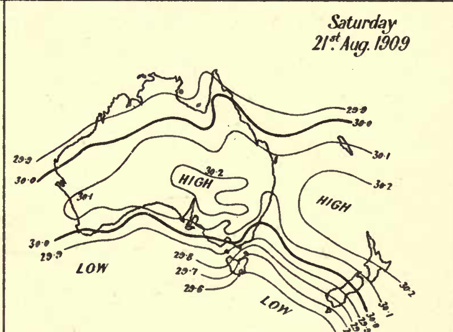



Fig. 82.

weather was anticipated, as this type of chart (19th) showing a deep cyclonic depression, wedged in between two energetic anticyclones, with isobars running approximately north and south, is a very favorable forerunner of widespread rains on the Australian continent, and the subsequent conditions more than realized these anticipations.

Up to the 18th the disturbance was marked by heavy rains, though only moderate winds, but on that day it began to develop cyclonic and electrical energy, and its subsequent career was accompanied by most violent atmospheric commotion. On the night of the 18th violent thunderstorms, with fierce squalls and heavy rain, broke over the far north-western and western areas of South Australia, and rapidly swept across the State into Victoria, rain falling at 153 stations in South Australia up to 9 a.m. next morning (19th), of which 52 registered between ½ and 1 inch, and 55 over 1 inch (maximum, 168, at Streaky Bay, on the west coast), and at 135 stations in Victoria, of which 26 recorded between ½ and 1 inch, and 21 others over 1 inch (maximum, Dimboola, 183). The rain area had also widened considerably, for light rain was still falling in Western Australia, and commencing in Tasmania.

By the 20th the storm had reached its greatest intensity, its cyclonic centre being clearly shown to the south of Victoria and near the north-west corner of Tasmania (barometer at Stanley, 28·96 inches), with exceptionally steep gradients. Along the south-east coast of South Australia the previous night the weather was extremely wild, with winds of hurricane violence and exceptionally low barometers, and rain fell throughout the whole of South Australia, Victoria, Tasmania, and New South Wales, and extended into the south-west and south of Queensland, being recorded at 155 stations in South Australia, of which 56 registered from ½ to 1 inch, and 8 over 1 inch (maximum, Uraidla, 169); at 156 stations in Victoria, of which 55 had between ½ and 1 inch, 56 from 1 to 2 inches, and 18 others over 2 inches (maximum, Kyneton, 325); at 31 stations in Tasmania, 9 being from ½ to 1 inch, 9 from 1 to 2 inches, and 3 over 2 inches (maximum, Burnie, 271); at 140 stations in New South Wales, of which 46 records were between ½ and 1 inch, and 10 over 1 inch (maximum, Tumbarumbah, 181); and light falls at 44 stations in Queensland. The last chart of the series shows that the disturbance had passed eastwards to the Tasman Sea and become of a simple "Antarctic" type while high pressures had become established over the continent. The isobaric distribution is of the ordinary winter type and fine weather returns.

A reference to the rain smears plotted with the isobars on Figs. 77–82 shows that it was in Victoria that the greatest overlap of the daily falls occurred. Hence, the floods were greatest in the rivers draining the Victorian highlands (see Fig. 76).

The series of heavy rains, accompanied by violent and prolonged thunderstorms, which set in over the western parts of this State in the early morning of the 19th August, gradually extended eastwards during the day, and was responsible for phenomenal floods in almost all the rivers in the western half of the State. These rains appear to have been at their greatest intensity along two parallel lines, one joining Warracknabeal and Queenscliff, the other Inglewood and Kyneton, and these give pretty nearly the direction in which the storm clouds were observed to be moving during the fifteen to twenty hours within which all the rain fell. East of Kyneton, the rains

lost their extraordinary character, but falls of over 1 inch were still the rule in all except the plains or country of relatively low level stretching from Echuca to Wodonga, and including Benalla, while in the more mountainous country the falls were generally between 1 and 2 inches. In Gippsland, owing to the mountain barrier to the north and west, the rainfall was generally insignificant, and actually nil around and east of the Lakes. The heaviest totals, above 4 inches, were received along a narrow strip of high country following the crest of the Dividing Range westward from Kyneton, and probably including the Pyrenees.

A brief summary of the heights reached in the various tributaries affected is appended :—

| River. | Town. | Height on Staff, &c. | Remarks. |
|---|---|---|---|
| Murray .. | Echuca .. | 32 ft. 2 in. .. | Twice exceeded (1867 and 1870) |
| Goulburn .. | Shepparton.. | 33 ft. .. | Only twice exceeded (by a few inches) since 1881 |
| Wimmera .. | Jeparit .. | 16 ft. | |
| Avoca .. | Charlton .. | .. | 6 inches above 1870 flood, and 4 feet above any others |
| Loddon .. | Laanecoorie | 36 ft. | |
| Campaspe .. | Rochester .. | 28 ft. 11 in. | |
| Murrumbidgee | Narrandera.. | 26 ft. 6 in. | Below the great flood of 1853. |

## (2) The Floods in the Darling Tributaries, January, 1910.*

The disastrous flood in the Upper Darling tributaries, consequent on the abnormally heavy rains on the north-western plains and slopes of New South Wales, as well as those on the Darling Downs of Queensland, is, from a meteorological stand-point, one of the most interesting events during 1910. These exceptionally heavy, continuous rains were caused by the joint action of an anti-cyclonic area over the southern half and the monsoonal depression operating in the northern half of the continent. The movements and subsequent development in intensity of this monsoonal tongue were meteorologically interesting. It was first truly delineated on the 7th January, as far south as Wilcannia, but on the 8th it had retreated to the south-west corner of Queensland. On the 10th, it protruded as far south and east as Albury, but withdrew the next day to the Queensland border, without, however, making any easterly progress. The high pressure had now intensified, though there had actually been a divergence of the isobars, due, no doubt, to the vapour-laden condition of the atmosphere. Within the next few days the tongue had expanded considerably, stretching as far south as Deniliquin, and on the 15th had intensified to such an extent as to form what is technically known as a closed curve depression. It was during this period that the heaviest falls were recorded. The Namoi Basin experienced particularly heavy falls on the 14th and 15th, and the average total rainfall for fifteen stations in that area from the 11th to the 15th inclusive was 8·63 inches, several places recording more than 12 inches of rain for that period. Copious falls occurred in the catchment area of the Condamine River, in Queensland, the average total for 26 stations from the 10th to the 17th inclusive being 4.71 inches. Cambooya and Dalby, both in this area, registered 10·17 and 9·68 respectively. The MacIntyre Basin was also unusually favoured, the average total for six stations, from the 10th to the 17th, being 7·13

* Australian Monthly Weather Report, January 1910, Commonwealth Bureau of Meteorology.

## WEATHER CHARTS.—FLOODS OF JANUARY, 1910.

FIG. 83.

11th Jany.

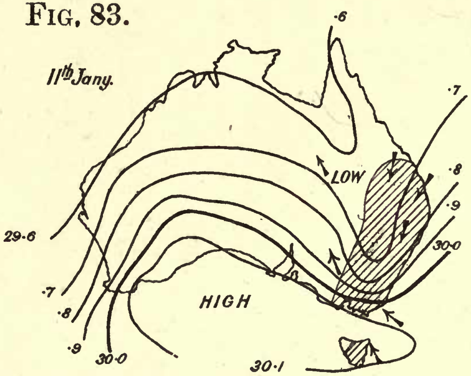



FIG. 85.

13th Jany.

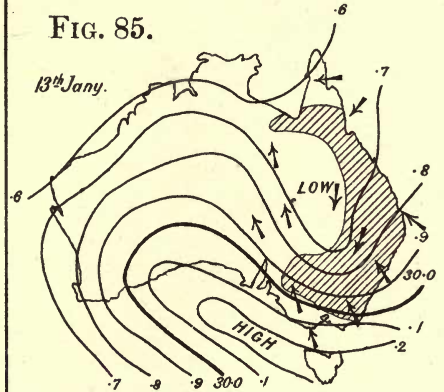



FIG. 87.

15th Jany.

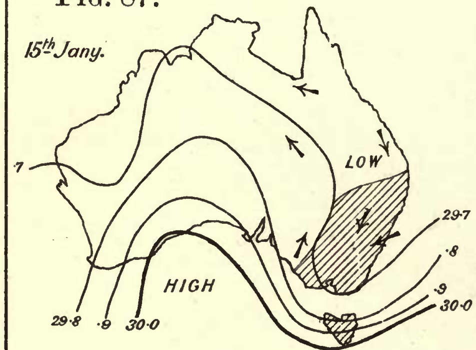



FIG. 84.

12th Jany.

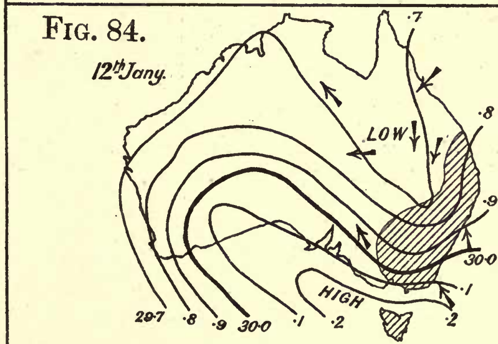



FIG. 86.

14th Jany.

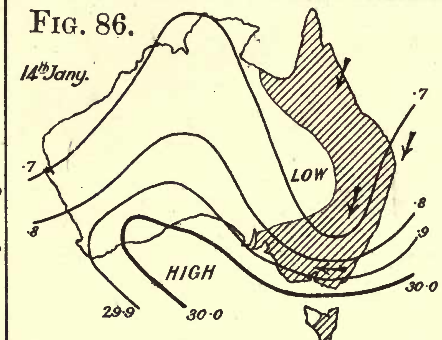



FIG. 88.


Flooded Areas. Jany. 1910

B- Bourke; Bi. Bingera; Br. Brewarrina; D- Dalby; M- Moree; N- Narrabri; T- Tamworth.

inches—Goondiwindi, 9·11; Umbercollie, 9·90; and Bingarra, 19·44 being the heaviest falls recorded. The enormous amount of water which fell over these districts, covering approximately 86,000 square miles, may be roughly estimated at 31,687,000,000 tons, or 7,100,000,000,000 gallons, the average total fall for the 77 rain recording stations from the 11th to the 15th inclusive being 5·7 inches. The very heavy falls in the Namoi Basin on the 14th and 15th, reaching as high as 6½ inches for 24 hours in some places, succeeding the moderately heavy falls of several days before, caused the flood in this tributary to rise higher than that in any other river. The water spread itself over the country for miles in every direction, devastating the surrounding districts and wreaking incalculable destruction of property, as well as causing some loss of life. Almost all the towns along its banks were inundated, Tamworth, Gunnedah, Manilla, Boggabri, Narrabri, and Wee Waa suffering particularly. Our observers report that this flood is the greatest since 1864, the water being 6 feet deep in the streets of Tamworth, while at Narrabri the river attained the greatest height ever known. The Gwydir and Barwon also reached record heights, both Moree and Brewarrina being partly submerged. Bourke appeared to be threatened with destruction. If the Queensland rivers, Condamine, Balonne, and Culgoa, which drain a large area and enter the Darling between Bourke and Brewarrina, had contributed their quota to the already flooded stream, Bourke must inevitably have been swept away; but, fortunately, this was not the case, as these waters did not reach Bourke till some days later. All the creeks and smaller water-courses were likewise in a flooded state, and the waters covered an extensive area. The thirsty plains would absorb an immense quantity of water on this account, as the contour of the country is conducive to such a result. Thousands of head of stock were drowned, and, generally speaking, the amount of damage was enormous.

### (3) Heavy Rains of Queensland.

The Queensland coast is characterized by occasional very heavy downpours. These are almost entirely confined to the summer months, as the following table (for storms giving over 10 inches during 23 years, 1887–1909) clearly indicates :—

| Month. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October | November. | December. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number .. | 104 | 42 | 92 | 24 | 1 | 9 | 1 | 1 | 2 | 0 | 2 | 26 |
| Per cent. .. | 33 | 14 | 31 | 8 | .. | 3 | .. | .. | 1 | .. | 1 | 9 |

The Map (Fig. 89) shows that a few large downpours have also occurred in the gulf country around Burketown. With these exceptions, only one other inland fall was recorded—at Monkira, in the far south-west. Here, over 11 inches fell on 1st February, 1906, the average annual fall (21 years) being 9 inches. This station forms a notable example of the necessity of long periods to arrive at a true mean In 1900 the annual rainfall was 2½ inches, and in 1906 it was 29 inches.

The following table gives the most important recent occurrences of these downpours in Queensland :—

| Amount | Station. | Locality. | Date. | Year. |
|---|---|---|---|---|
| 35·71 | Crohamhurst .. | 45 miles north-west of Brisbane .. | 31st January .. | 1893 |
| 26·20 | Buderim .. | North of Brisbane .. .. | 11th January.. | 1898 |
| 25·12 | The Hollow .. | Mackay .. .. .. .. | 23rd February | 1888 |
| 23·33 | Macnade .. | Townsville .. .. .. | 6th January .. | 1901 |
| 23·07 | Yeppon .. | Rockhampton .. .. .. | 31st January .. | 1893 |
| 22·17 | Dungeness .. | Cardwell .. .. .. | 16th March .. | 1893 |
| 21·53 | Mooloolah .. | North of Brisbane .. .. | 13th March .. | 1892 |
| 22·22 | Innisfail .. | South of Cairns .. .. .. | 29th December | 1903 |
| 21·00 | Nambour .. | South of Gympie .. .. .. | 9th January .. | 1898 |
| 20·08 | Yandina .. | South of Gympie .. .. .. | 1st February .. | 1893 |
| 20·05 | Yeppoon .. | Rockhampton .. .. .. | 31st January | 1893 |
| 19·55 | Crohamhurst .. | 45 miles north-west of Brisbane .. | 9th January .. | 1898 |
| 19·55 | Howard .. | Maryborough .. .. .. | 15th January | 1905 |
| 19·20 | Townsville .. | North Coast .. .. .. | 24th January | 1892 |
| 18·24 | Cardwell .. | North Coast .. .. .. | 18th March .. | 1904 |
| 18·31 | Brisbane .. | South Coast .. .. .. | 21st January | 1887 |
| 18·07 | Thornborough | Near Cairns .. .. .. | 20th April .. | 1903 |
| 18·20 | Anglesey .. | Gympie .. .. .. .. | 26th December | 1909 |
| 18·05 | Yeppoon .. | Rockhampton .. .. .. | 8th January .. | 1898 |
| 17·40 | Bloomsbury .. | Brisbane region .. .. .. | 14th February | 1893 |
| 17·95 | Mundoolun .. | South of Brisbane.. .. .. | 21st January | 1887 |
| 17·75 | Palmwoods .. | Brisbane .. .. .. | 25th December | 1909 |

These phenomenal rains are seen to be most abundant between Cairns and Cardwell. The great number recorded in the Brisbane district is largely due to the fact that here the rain-gauges are well distributed and fairly numerous, which is not the case in the less settled regions of Queensland.

### (4) Flood Rains in Western Australia.

Perhaps the most striking region in Australia for examples of abnormal rainfall is in the far north-west in Western Australia (Fig. 90). Here the 10-in. annual isohyet passes near many stations which have recorded more than that amount in one rainstorm, though of course falls of this type are few and far between. Some of the heavier falls are given in this table, where a comparison with the average annual amount should be found of interest in many cases :—

| Inches. | Station. | Position. | Date. | Year. | Average Annual Rainfall. | Number of Years. |
|---|---|---|---|---|---|---|
| 36·49 | Whim Creek | Near Cossack | 2nd and 3rd April .. | 1898 | 19·87 | 14 |
| 27·06 | Whim Creek | Near Cossack | 20th and 21st March | 1899 | 19·87 | 14 |
| 24·18 | Thangoo .. | Near Broome | 17th and 19th February | 1896 | 22·61 | 17 |
| 21·42 | Yeeda .. | Near Derby .. | 28th, 29th, and 30th December | 1898 | 23·66 | 21 |
| 20·82 | Wyndham .. | Long., 128°, lat., 15° S. | 11th, 12th, and 13th January | 1903 | 27·27 | 25 |
| 20·40 | Balla .. | Near Cossack | 20th and 21st March | 1899 | 17·98 | 6 |
| 20·23 | Derby .. | King Sound .. | 29th and 30th December | 1898 | 26·38 | 26 |
| 20·12 | Cossack .. | Long., 117°, lat., 21° S. | 15th and 16th April | 1900 | 12·01 | 30 |
| 17·47 | Obagama .. | Near Derby .. | 16th, 17th, and 18th February | 1896 | 34·48 | 16 |
| 15·25 | Boodarie .. | North-east of Cossack | 3rd and 4th January | 1894 | 12·49 | 24 |
| 14·53 | Boodarie .. | North-east of Cossack | 21st March .. | 1899 | | |

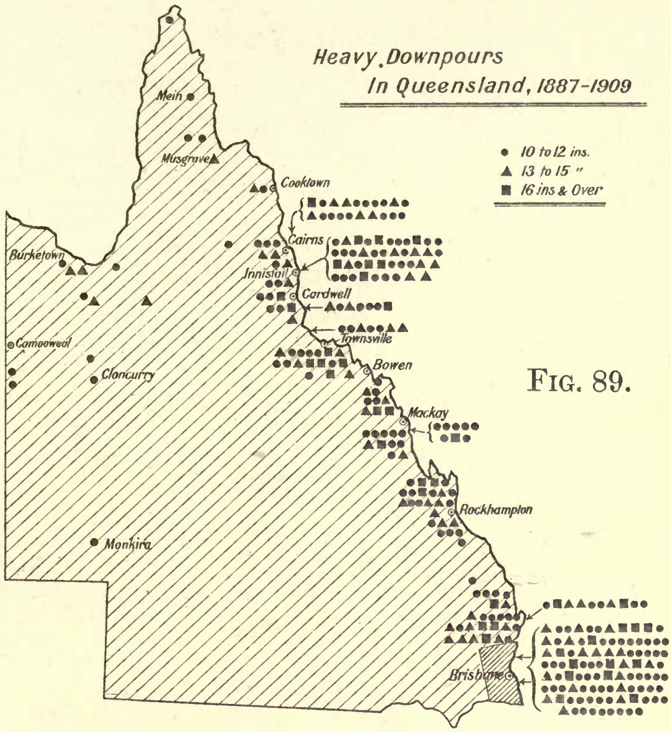

Heavy Downpours
In Queensland, 1887-1909
10 to 12 ins.
13 to 15 "
16 ins & Over
Mein
Musgrave
Cooktown
Burketown
Cairns
Innisfail
Cardwell
Townsville
Camooweal
Bowen
Cloncurry
Mackay
Rockhampton
Monkira
Brisbane

Fig. 89.

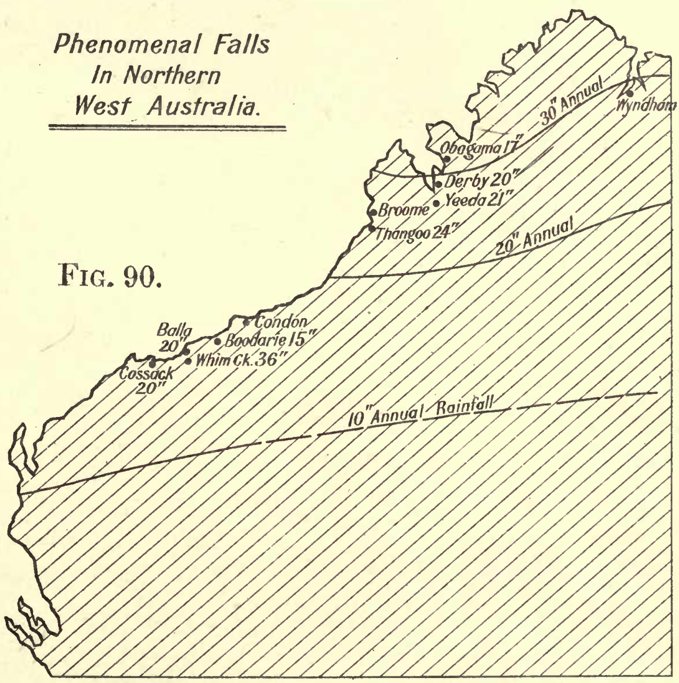

Phenomenal Falls
In Northern
West Australia.
30" Annual
Wyndham
Obagama 17"
Derby 20"
Yeeda 21"
Broome
Thangoo 24"
20" Annual
Condon
Balla 20"
Boodarie 15"
Whim Ck. 36"
Cossack 20"
10" Annual Rainfall

Fig. 90.

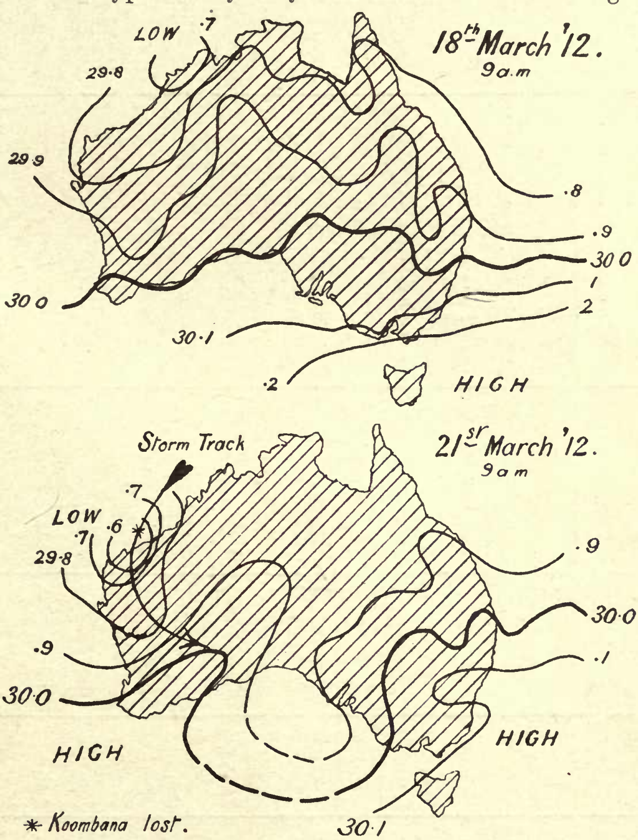
## XI.(A).—WEST AUSTRALIAN HURRICANES.

Undoubtedly the most striking feature of the climate of Western Australia is the visitation of the north-west coast by hurricanes, locally known as "willy-willies," in the summer months.

These occur in connexion with, or are very violent forms of, cyclonic disturbances which originate over tropical seas, and are practically limited to the summer months—December to April inclusive.

"These storms sometimes give the first indication of their approach in the extreme north-eastern corner of the State, and occasionally it is believed at Port Darwin. They travel at first in a south-westerly direction, the centre keeping well out to sea; and their pressure and movement are shown by an easterly wind gradually veering north and west, accompanied by heavy rainfall. When they reach latitude 20° or thereabouts, their course alters and they recurve and commence to travel in a southerly or south-easterly direction, striking the coast generally between Condon and Fortescue, and frequently bring a "willy-willy" to wreck whatever happens to be in the way. They now travel inland, passing, as a rule, either over or to the east of the gold-fields, and bringing more or less rain according to their intensity. Thence they travel to the Southern Ocean." *

The path of a typical willy-willy disturbance is shown in Figs. 91–92.




FIGS. 91–92.

* Meteorological Report, Western Australia, 1902, p. 6.

## Hurricanes in Western Australia.

(*Tropical Cyclones or " Willy-Willies."*)

| Year. | Month. | Time of Maximum. | Chief Locality. | Direction of Movement. | Rain. | Remarks, Pressure, Minima, &c. |
|---|---|---|---|---|---|---|
| 1872 | No parti | culars availab | le. | | | |
| 1877 | Feb. .. | 15 to 18th .. | Lacepede Island (N. of Broome) | From N.E. .. .. | Not tabulated .. .. | Barometer, 29·49. Winds veered from E.S.E., E., N., N.E. |
| 1878 | Dec. .. | 24th .. | Lacepede Island | .. .. .. .. | ,, .. .. | Barometer, 29·52. Wind at maximum from N.W. *Runnymede* lost |
| 1879 | Jan. .. | 23rd .. | Broome | | | |
| ,, | ,, | 25th, 5 a.m. | Roeburne .. | Towards S.W. .. .. | ,, .. .. | Barometer at Roeburne, 28·92. *Sulina* and *Manfred* lost |
| 1880 | ,, .. | 9th .. | Yarnmadarra Creek | .. .. .. .. | ,, .. .. | *Adalia* lost. Tidal wave 25 feet over H.W.M. |
| 1881 | ,, .. | 7th .. | Cossack .. | Started Cape Carney; moved along coast to Cape Lockyer | ,, .. .. | Barometer, 26·00, on *Alpha* (doubtful); four pearling boats reported 27·00. Many luggers lost. Wind veered from N.E. to N.W. |
| 1882 | Mar. .. | 7th, at 9 p.m. | Roeburne .. | Extended 25 miles E. and 50 miles W, but no distance inland | 6½″ at Cossack .. .. | More severe than 1872. Barometer at Cossack, 28·1. Wind from E.N.E. at maximum |
| 1887 | Feb. .. | 12th .. | .. .. | .. .. .. .. | Cossack, 8·6″ .. .. | Barometer, 29·176, at Cossack |
| ,, | Apl. .. | 22nd .. | S.W. of Wallal 90-mile Beach | .. .. .. .. | .. .. .. .. | Over 200 lives lost |
| 1888 | Jan. .. | 7th, 8th .. | Derby .. .. | .. .. .. .. | Wyndham, 4″; Derby, 17″ | Barometer at Derby, 29·134. Wind S.E., E., and later N.W. |
| ,, | Apl. .. | 22nd .. .. | 90-mile Beach .. | .. .. .. .. | .. .. .. .. | Many pearling boats lost, and 114 men drowned |
| 1889 | Mar. .. | 1st | Roeburne .. | Travelled from near Broome to near Onslow | Roeburne, 5·9″; Onslow, 3·4″; Fortescue, 5″ | A " circular hurricane," *i.e.*, wind veered from S. through N.E. to W. Three boats wrecked near Cossack |
| 1890 | Jan. .. | 27th .. | Kimberley .. | .. .. .. .. | Wyndham, 11·6″; Derby, 5·4″ | Barometer, 29·357, at Wyndham |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1897 | Dec. .. | 26th, 10.30 a.m. | Onslow .. | Travelled from Onslow to Eucla, 30th | Port Hedland, 5•9″; Condon, 5•3″; Onslow, 2″; Towara, 6•5″ | Minimum barometer, 28•57; wrecked Onslow. Terminated a hot spell in Victoria on 31st |
| 1898 | Apl. .. | 2nd, 5 p.m... | Cossack .. | From Wyndham, 29th; through Derby and Broome, 30th; to Cossack | Bamboo Creek, 16″; Whim Creek, 36″; Cossack, 15″ | Wind at Cossack (at maximum of gale) as a hurricane from east, evidently towards deep barometric depressions at sea; s.s. *Albany*, 27•8. All boats in creek at Cossack, except police boat, wrecked |
| 1899 | Jan. .. | 12th .. | Off Wyndham (see map) | Along coast to Condon, then recurved and traced to Tasmania | Marble Bar, 7″; Nullagine, 9″; Mt. Margaret, 3″, on 16th | s.s. *Tangier* encountered "willy-willy" on 12th off the N.W. coast |
| 1900 | Mar. .. | 5th, at 3.15 p.m. | Cossack .. | Along coast from N.E.. passed inland south of Cossack, and then crossed the gold-fields to the Bight | Wyndham, 3″; Derby, 5″, 3rd and 4th; Marble Bar, 6″, 6th; Cossack, 8″, 6th; Cue, 1½″, 9th; Laverton, 2″, 10th; Whim Creek, 13″, on 5th and 6th | Minimum barometer, 29•34. Hurricane from S.W., not so disastrous as previous cases. 13″ of rain fell at Whim Creek, near Cossack, on the 5th and 6th. The value of these violent disturbances in bringing rain to the interior is obvious |
| ,, | ,, .. | 6th, at 8 a.m. | Onslow (see map) | | | |
| 1901 | Jan. .. | 30th .. | s.s. *Australind*, south of Java | Storm travelling W.S.W. .. | .. .. .. .. | Ship hove to. Barometer, 29•36. A very interesting hurricane, for its course at sea can be traced from reports of the *Australind* |
| ,, | Feb. .. | 7th .. | Cossack .. | Approaching coast from W. | Port Hedland, 13″; Peak Hill, 3″, 8th; Eastern Gold-fields, 3″, on 9th | Barometer at Condon, 28•78. Apparently same storm as above |
| 1902 | ,, .. | 9th, at 12.30 p.m. | ,, .. | Travelled along the coast from Wyndham to Cossack, thence inland to Coolgardie and Eyre | Hall's Creek, 4″, 2nd to 6th; La Grange, 7″, 4th–8th; Condon, 7″, 9th–10th; Peak Hill, 3″, 10th–11th; Menzies, 3″, on 11th | Barometer, 29•03, was the minimum recorded at Cossack. "Willy-willy" did a good deal of damage at Cossack. Prior to rains the clouds in the interior were moving from N. to N.W. |
| 1903 | Jan. .. | 10th .. | Off East Kimberley Coast | Recurved north of Broome on 16th; passed inland just touching east of gold-fields; thence to South Australia | Wyndham, 25″, 9th to 13th; Turkey Creek, 10″; Hall's Creek, 6″; Quanbun, 2″; Menzies, 1•7″, on 19th | Wind not so severe as usual. Barometer only fell to 29•65 |
| 1904 | Apl. .. | 17th .. | Off Broome, 30 hours | .. .. .. .. | Broome, 5•5″; Yeada, 8″ .. | Schooner *Star of the West* wrecked |

## Hurricanes in Western Australia—*continued.*

| Year. | Month. | Time of Maximum. | Chief Locality. | Direction of Movement. | Rain. | Remarks. Pressure, Minima, &c. |
|---|---|---|---|---|---|---|
| 1905 | Feb. .. | 8th .. | Onslow .. | From N.W. coast across interior to the Bight | Onslow, 1·5″; Fortescue, 2·7″; Carnarvon, 2″; New Forest, 7″; Field's Find, 2″ | Barometer at Onslow, 29·11; damage to shipping and loss of life |
| 1907 | Jan. .. | 14th .. | La Grange .. | .. .. .. .. | Wallal, 8·4″; La Grange, 4″; Broome, 6″ | Barometer at Broome, 29·51. Heavier gale than April, 1908 |
| „ | Mar. .. | 13th, 14th .. | .. .. | From Kimberley down coast to Shark's Bay; thence across continent to the Bight | Cossack, 13·5″, 11th to 15th; Chinginana, 7″, 9th to 16th; Winning Pool, 3·5″; Clifton Downs, 4·2″, 15th; general heavy rain throughout North-west Gascoyne and gold-fields, reaching Eyre, 2·3″, on 17th | *Mildura* wrecked. Barometer at Onslow, 29·30, on 14th; and at Yalgoo, 29·24, on 15th. No heavy winds reported |
| 1908 | Apl. .. | 26th and 27th (midnight) | La Grange Bay (Broome) | Broome to Wallal (180 miles to S.W.) | Derby, 3″; Broome, $8\frac{1}{2}$″; La Grange, $5\frac{1}{2}$″; Bohemia Downs, 5·6″ | Barometer, 29·54. Pearling fleet wrecked; damage, £40,000; 50 lives lost. Apparently a local hurricane |
| „ | Dec. .. | 8th .. | La Grange to Wallal | .. .. .. .. | La Grange, 3·9″; Wallal, 8·5″; Eel Creek, 2·5″; Red Hill, 2·6″ | *Cutty Sark* wrecked |
| 1909 | Jan. .. | 19th, 11.45 p.m. | Onslow .. | Moving S.E. over Onslow .. | Onslow, 8·8″; Leonora, 5″, on 21st | Barometer at Onslow, 28·945. E.N.E. wind at maximum force of gale. Four luggers and 24 men lost |
| „ | Apl. .. | 6th, noon .. | „ .. | Moving towards S.S.E. over Onslow; thence overland to South Australia | Onslow, 5·4″; Yaurie, 6″; Bangomall, 3·5″; Abbotts, 2·6″ | Barometer at Onslow, 29·188 |
| 19 0 | Nov. .. | 19th, at 2 p.m. | Broome .. | On the 19th a marked "low" moved over Broome from the sea; on 20th over La Grange; on 21st dissipated | Broome, 11″; Derby, 5·7″; La Grange, 7·4″; Rollah, 10″ | Twenty-six luggers and 40 lives lost. This hurricane did not give a well-marked track. Barometer at Broome, 28·64 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1911 | Feb. .. | 7th, at 4.30 a.m. | Onslow .. | Moving down the coast from N.E. to Carnarvon | Whim Creek, 6″, on 7th; Winning Pool, 3″, on 8th | Barometer, minimum 28·77. at Onslow, and Wind E.S.E. *Glenbank* wrecked off Legendre Island at 9 p.m. on 6th. All the crew drowned but one man |
| 1912 | Mar. .. | 6th .. | Broome .. | .. .. .. .. | Broome, 7″, from 4th to 6th; La Grange, 8·7″ | Barometer, 29·33. |
| ,, | ,, .. | 21st, at 11 p.m. | Cossack (see map) | From N.E. to Cossack; and thence to Murchison and Coolgardie Gold-fields | Cossack, 9″; Nullagine, 4″, Tambrey, 6·6″ | Barometer, minimum 28·86. Wind changed from east through south to west during the hurricane at Cossack; *Koombana* wrecked off Condon; all lives lost |

The hurricanes are thus most numerous in the hottest months. Of the thirty-one tabulated above—

| | | | | | |
|---|---|---|---|---|---|
| January | has | nine; | April | has | six; |
| February | ,, | six; | December | ,, | three; |
| March | ,, | six; | November | ,, | one. |

In these months there is a very hot region situated between Nullagine anc Winning Pool, Western Australia. This area of high temperature means also an area of low pressure, and this is no doubt a factor in swinging the hurricane to the south-east. The cold Westralian current may act as a buffer to the passage of these cyclones along the coast beyond Onslow; the general easterly drift of the upper air also undoubtedly helps to swing them inland from Cossack. Moreover, their destructive violence rarely penetrates far beyond the coast, for this can only be maintained by large supplies of ascending moist air. This can only take place over the ocean, so that though an individual cyclone can be traced to Coolgardie, to Eucla, and even to Tasmania, it rarely inflicts much damage inland, but, as noted in the pre ceding table, rather brings beneficial heavy rains.

## XI.(B).—Hurricanes in the South-Western Pacific.

In the warm, moist, and calm region of the north-east coast of Queens land, hurricanes develop just as in the similar area north of Wester Australia.

Owing, however, to the fact that their parabolic paths do not approac the land so closely as in Western Australia, we have very little data of thei behaviour. They originate generally between Fiji and New Guinea, and move westward to Queensland. They usually hit the coastline near Cairns and then "rebound" to the south-east—being carried thither by the domi nant upper currents as in the western examples. Occasionally their path can be traced from shipping reports; but very often it is not possible t obtain mainland data, for the telegraphic and postal services are nearl always greatly disorganized for some time after the disaster. Two example are briefly described, which will give some idea of their character.

### The Fiji Hurricane, March, 1910.

(Figs. 93–96.)

On the night of the 24th, and early morning of Good Friday, the Fi group of islands was visited by a tropical hurricane of exceptional severity doing damage roughly estimated at over £250,000. The storm was a remark able one, and its track can be followed for some 2,500 miles from Fiji to Ne Caledonia, Norfolk Island, and the North Island of New Zealand. Th disturbance developed to the north-east of the Fijian group, and, movin in an approximately south-westerly direction, it travelled over Vanua Lev and across to Viti Levu, passing close to Levuka and a little north of Suv The Rewa River and the town of Nasouri, near its mouth, suffered most, fo the full force of the hurricane came down the Rewa Valley. At Nausori th sugar mill was blown down, nearly every house in the town unroofed, an many totally destroyed; the river in places rose 35 feet, and every boa moored foundered. The banana, cane, and tobacco plantations were prac tically wiped out, and hundreds of settlers ruined. A number of native and Indians were killed, but, fortunately, the death roll was comparativel small, considering the violence of the storm. The force of the wind wa almost incredible. At Nausori, a press correspondent of *The Argus* state that "churches, well built on concrete piles, were lifted bodily and dumpe

# FIJI HURRICANE.

## March 1910

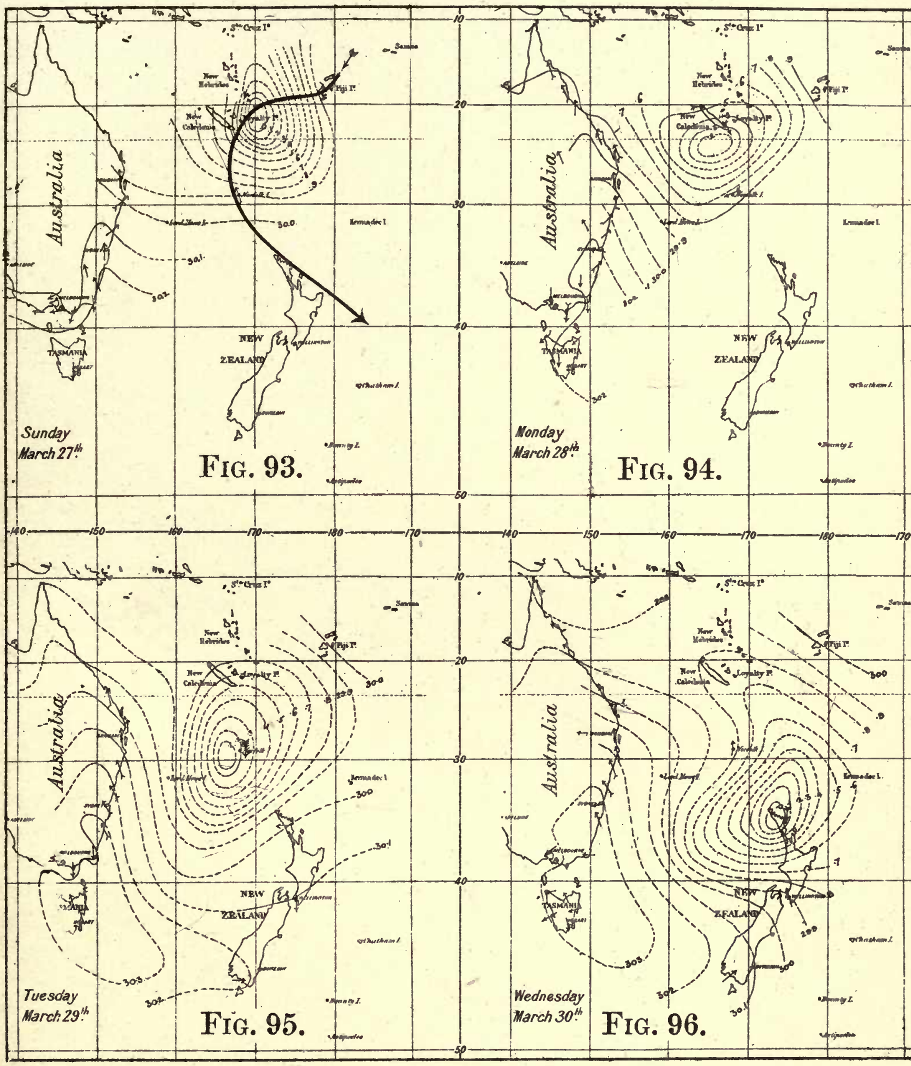



FIG. 93. FIG. 94. FIG. 95. FIG. 96.

yards away. One well-found house of four large rooms and verandah all round was shifted 52 feet. Another 3 feet would have put it over the hill. A new two-story concrete house was cut in half, the upper portion going."

Apparently the hurricane came down upon the group without any of the usual barometric warnings. Captain Wooley, the harbor-master at Suva, reports that "it was a most extraordinary and most unexpected happening; the barometer showed no signs to speak of, as we often have a very much larger drop than shown on the 24th at 4 p.m. I was on a trip, but put back at 5.30 p.m. owing to the excessive heat, for although we were having a fresh south-east breeze, it was beyond anything I had ever experienced in similar weather. On the evening of the 24th there were no signs of dirty weather, except this heated wind; from 6 to 10 p.m. there was a moderate easterly wind with some rain; at midnight, barometer falling and wind increasing; 2 a.m., barometer 29·000 inches, increasing wind from east with heavy rains; 3 a.m., blowing with hurricane force, house started to go, impossible to venture out, sheets of iron flying from all directions from east to north-east; at 4 a.m., the barometer started to rise and the wind fell; 5 a.m., back to only a north-north-east gale, with heavy torrents of rain." At Suva, the storm was at its maximum about 4 a.m., when the barometer read 28·50 inches; at Levuka, the lowest reading was 28.64; and at Nausori, 28·40. At Levuka, there was a calm of ten minutes or more, then a complete change of wind from south-east to north-west, showing that the eye of the storm passed right over the town, but at Suva there was only a steady easterly blow backing north north-east as the barometer rose.

The storm swept over Bau in Fiji, leaving only four houses out of 100 standing. Hence it pursued a westerly course through the New Hebrides. Here the storm centre passed near the island of Tanna. In Mare, one of the Loyalty Islands, three storm waves destroyed houses and plantations. On Easter Sunday, it swept down on Noumea, New Caledonia. Here small coasting boats, barges, and the steam launch *Obus* were sunk in the bay of Moselle, and the town of Noumea was considerably damaged.

### Norfolk Island.

After passing New Caledonia and recurving to the south-west of the island, the storm pursued a southerly course to Norfolk Island, covering the intervening distance in about 26 hours. Dr. P. Herbert Metcalf, the Deputy Chief Magistrate, reports that the barometer fell to 28·882 inches, with a gale of hurricane violence in the east, but, except to trees and gardens, there was little damage done. No houses or persons were injured. The following are his meteorological notes before and after the passage of the storm:—

28th March, 9 a.m.—Dull, damp, and drizzly. Barometer, 29·538 (uncorrected 383 feet above sea-level). Wind, east; force, 7.

28th March, 9 p.m.—Barometer, 29·192, falling fast. Wind, force, 10. Rain pouring down.

28th March, 9.45 p.m.—Barometer, 29·062.

29th March, 1.30 a.m.—Barometer, 28·882. Awful gale from east. (The barometer fell no lower with me; was up many times in the night to look.)

29th March, 9 a.m.—Barometer, 28·970. Wind, north-east; force, 11. Rain recorded, 2·65 inches.

Then came a rapid rise in the barometer; the evening of the 29th was fine and fairly calm.

30th March, 9 a.m.—Barometer, 29·542. Wind, westerly; force, 4. Trees fell chiefly from north-east to south-west.

This storm system was remarkable in that it retained its cyclonic form and energy over so long a period. Usually tropical disturbances spread out over a wider area on reaching higher latitudes and lose their vigour, but in this instance, as shown by the following table giving the lowest barometer readings along its track, the disturbance retained its intensity in a very remarkable degree throughout its whole path:—

| | | | Barometer. |
|---|---|---|---|
| March | 24 | Levuka (Fiji) | 28·64 inches |
| „ | 24 | Nausori (Fiji), 10 p.m. | 28·80 „ |
| „ | 25 | Nausori (Fiji), 3 a.m. | 28·40 „ |
| „ | 25 | Suva (Fiji), 2 a.m. | 29·00 „ |
| „ | 25 | Suva (Fiji), 4 a.m. | 28·50 „ |
| „ | 27 | New Hebrides, 3–4.30 a.m. | 28·28 „ |
| „ | 27 | Noumea (N.C.), 11.30 p.m. | 28·42 „ |
| „ | 29 | Norfolk Island, 1.30 a.m., &c. | 28·88 „ |
| „ | 30 | Russell (N.Z.), 9 a.m. | 29·00 „ |

The series of isobar charts which accompany this report shows that the disturbance followed the usual track of storms generated in the southern tropical zone, and first moved in a west and south-westerly direction, until caught in the easterly atmospheric drift of mid-latitudes, when it curved off to the south-east. They also clearly confirm what has been before established, that storms originating in the vicinity of the Fiji and other groups of islands east of New Caledonia are likely to affect the northern parts of New Zealand later. New Zealand has thus ample warning of the coming of the cyclone, and the Dominion Meteorologist, the Rev. D. C. Bates, was enabled to advise all the North Island coast stations some two or three days beforehand of the storm approaching.

The large monsoonal storm system which crossed the continent in the early part of the month, the continued monsoonal disturbance and heavy rains in Queensland later, and the development of the Fiji hurricane, are evidence of unusual activity in the southern monsoonal low pressure belt during March, and it would be interesting to ascertain whether a similar activity was shown in other parts of the Southern Hemisphere.

### Port Douglas, March, 1911.

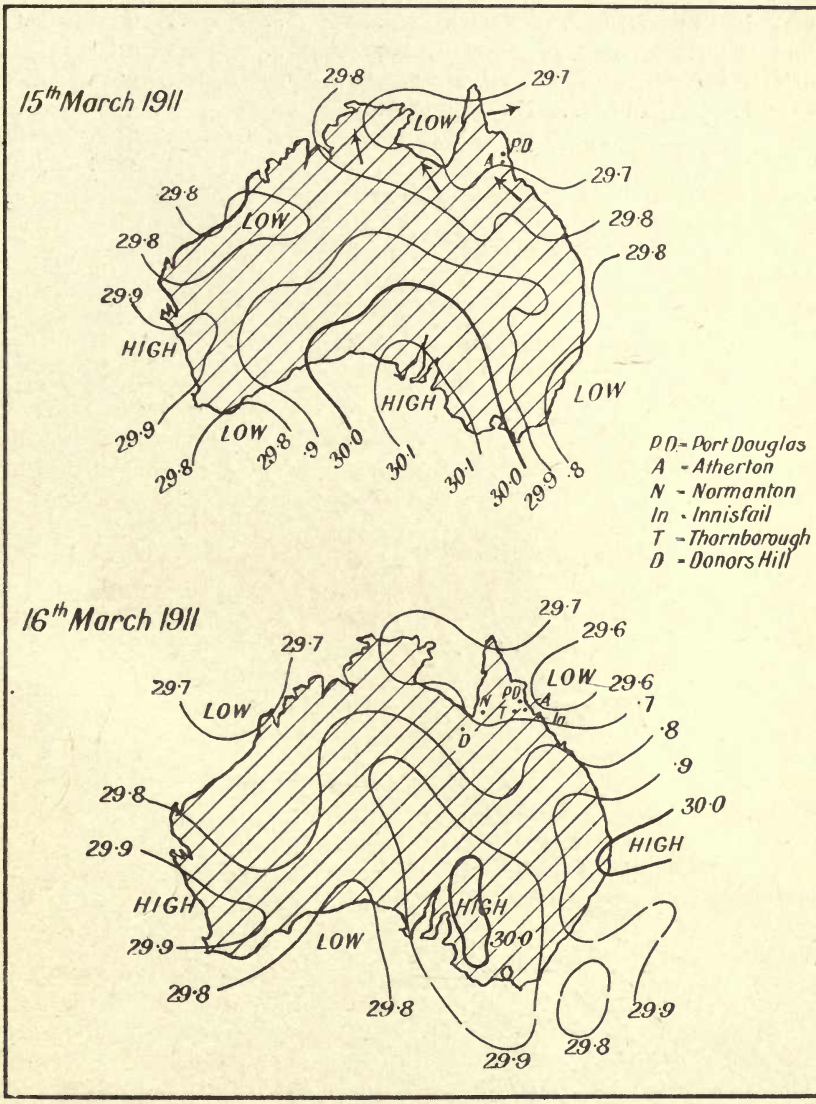
On the North Queensland coast, March is perhaps the month most liable to tropical hurricanes. In 1911 (16th March), a disastrous storm struck Port Douglas, killing several people and almost destroying the town.

A brief description of the hurricane is as follows:—

Until the 13th, a tongue-shaped shallow depression remained persistently over the north-western quarter of the State and the Gulf of Carpentaria without developing unsettled characteristics of any definite kind. On the 14th data showed that the trough was undergoing a deepening process and

under the impetus of vigorous high-pressure waves from the westward, was moving slowly across the Peninsula (Figs. 97–98). This deepening was maintained, and on the 16th a disturbance was evolved with its centre approximately a little to the north-east of Cairns. It suddenly moved towards the

# QUEENSLAND HURRICANE




FIGS. 97–98.

coast, between Cooktown and Cardwell, and its worst effects were experienced in the Port Douglas District, which it swept with disastrous results to property and life.

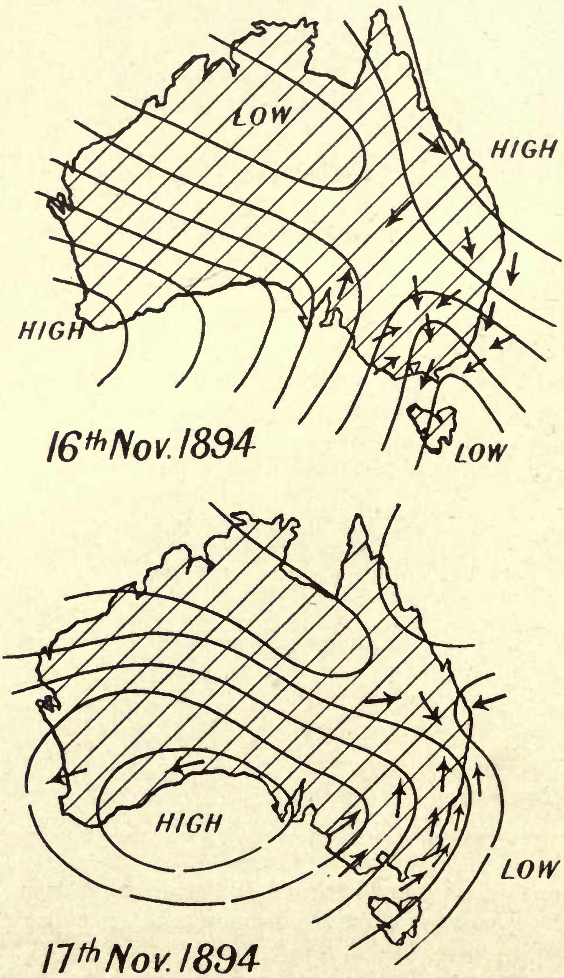
During this hurricane the fine steamer *Yongala* was lost, with all on board.

It subsequently moved on a westerly course, rapidly decreasing in intensity, and remained over the Gulf of Carpentaria until the 21st, causing unsettled conditions in the north-western interior.

This storm obviously did not follow the parabolic path characteristic of the more typical tropical hurricanes. It, however, caused very heavy precipitation all along its track, as the following 24 hours' totals show :—

| | | |
|---|---|---|
| 16th and 17th .. | Innisfail .. .. .. | 6·05 inches |
| | Atherton .. .. .. | 6·20 ,, |
| | Thornborough .. .. | 4·78 ,, |
| 17th and 18th .. | Normanton .. .. .. | 4·05 ,, |
| | Donor's Hill .. .. .. | 3·08 ,, |
| | Atherton .. .. .. | 1·26 ,, |

## XI.(c).—Southerly Bursters.




Figs. 99–100.

These winds have been described as perhaps the most remarkable of the "squall" winds which characterize various parts of the earth.

They are cold winds, succeeding a period of hot weather. They blow from the south, usually arriving as a sudden squall after calms or northerly winds.

Although not unknown along the southern shores of Australia, it is the coast of New South Wales, from Port Macquarie to Cape Howe, where they are especially noteworthy. Here the topographic conditions are peculiar, and are undoubtedly contributing causes to the local intensity of the burster.

Some 50 or 80 miles from the coast extends a belt of highlands from 3,000 to 7,000 feet high. They are parallel to the coast and therefore at right angles to the general easterly atmospheric drift. Between this cooler belt of highlands and the ocean is a "hinterland" which is considerably warmer than the ocean or the mountains during the summer months when these winds chiefly occur.

The monthly averages for the bursters are as follows:—

| | | | |
|---|---|---|---|
| January .. | 17·3 per cent. | August .. | ·5 per cent. |
| February .. | 13·2 " | September | 6·3 " |
| March .. | 9·1 " | October .. | 14·0 " |
| April .. | 4·1 " | November .. | 16·8 " |
| May .. | ·4 " | December .. | 18·3 " |

So that the spring and summer half-year accounts for 86 per cent. of the bursters.

The average of their maximum velocities is 42·7 miles per hour, though 153 miles was recorded in 1877.

(The maximum velocity occurs usually about twelve hours after the burst.)

The weather preceding the burster may be summarized as follows:—For a period varying from three hours to three days before high temperatures prevail, northerly winds, with a tendency to east in summer, and to west in early and late summer, are the rule.

The clouds are characteristic. Usually cirro-cumulus and thunder clouds appear in the south-west, then a long dark cumulus roll approaches with a front of 30 miles or more. As this approaches the wind drops completely, and then a whirl of dust ushers in the "burst." The windvane flies round to the south, and the southerly in a few minutes may reach gale force.

Rain may accompany the burst, but it is generally due to the electrical disturbances. The warm antecedent north winds are, however, occasionally accompanied by some rain.

The southern swing in wind direction is accompanied by a very rapid fall in temperature on occasions amounting to as much as 37° Fah.; 18° is about the average total fall, but on the 30th December, 1891, the thermometer dropped this amount in the first five minutes.

## Origin.

There is no doubt that the burster is merely an intensification of the normal southerly wind ushering in an anti-cyclone in New South Wales. This intensification is at least partly due to the relation of topographic and temperature conditions noted previously.

The following are some of the factors which have to be considered in discussing this phenomenon :—

(1.) The effect of the friction of the land mass, combined with differences of latitude, in gradually tilting the axis of the $\Lambda$-depression, so that as it passes New South Wales, it tends to lie N.W. and S.E.

(2.) The differences between the wind forces over land and water for the the same barometric gradients.

(3.) The convectional effects of the evaporation from the warmer waters off the East coast of Australia.

(4.) The effect of the ridges of the Kosciusko Ranges, which attain a height of over 5,000 feet for nearly 100 miles, in delaying the Eastward advance of the "highs" and "lows."

That "lows" coming from the West are intensified as they reach the warm coastal waters of New South Wales is a matter of common observation, as is the tendency for cyclonic storms to form there, and persist for days at a time. This is probably due to factor (3) above. If we assume that the Northern portion of a passing Antarctic depression undergoes a decided deepening from this cause, and that the axis of the depression is tilted slightly towards the N.W., as suggested in (1), the winds in rear of the trough will not only be strengthened by the fall in the barometer, but will come from a point sufficiently near Southerly to blow mostly over water. The two factors will, therefore, assist one another in increasing the force of the Southerlies.

As regards the influence of the Kosciusko Ranges, it may be premised that they have a greater retarding influence upon the "highs" than the "lows," since the increase of atmospheric density downwards near the surface is greater in "highs" than in "lows," and this may cause the change to anticyclonic high pressures along the New South Wales coast to be delayed slightly, and then to be more sudden than elsewhere, causing a temporarily steep barometric gradient on the rear side of the trough with corresponding wind force. Some influence may be traceable also to the contrast between the cooling effects of the Alpine summits, partly covered with melting snows, and the abnormal warmth of the strip of country lying between the mountains and the coast.*

## XII.(A).—FORECASTING.

In framing official predictions of the weather the daily synoptic and isobaric chart is the chief evidence relied upon.

To forecast with any degree of accuracy requires considerable experience, a knowledge of the distribution of the normal local climatic elements, and a due appreciation of the significance of the varying features of atmospheric systems and the degree to which they are affected by latitude, longitude, the seasons of the year, and, at times, even by the prevailing conditions of the land surface over which the atmospheric systems are passing.

The methods of working in the Commonwealth Meteorological Organization are similar to those adopted in all kindred scientific institutions in other countries.

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* For fuller discussion of this subject see "Essay on Southerly Bursters," by H. A. Hunt, Proceedings of the Royal Society of New South Wales, 1894.

Synchronous observations are received by telegraph from a number of stations from as wide an area as possible.

The following table gives the number and equipment of stations reporting daily to the Central Bureau :—

| — | 9 a.m. Reports. | | | 3 p.m. Reports. | | 6 p.m. Reports. |
|---|---|---|---|---|---|---|
| | Stations with Instruments. | Wind, Weather, and Rain Report. | Rain only (when any). | Instrument Stations. | Wind and Weather. | Rain only. |
| Western Australia | 34 | .. | 72 | 1 | .. | .. |
| South Australia | 18 | 4 | 72 | 4 | .. | .. |
| Queensland .. | 40 | .. | 59 | 1 | .. | .. |
| New South Wales | 15 | 1 | 99 | 2 | .. | .. |
| Victoria .. | 45 | 150 | 10 | 27 | 5 | 158 |
| Tasmania .. | 12 | .. | 19 | 1 | .. | .. |
| New Zealand .. | 3 | .. | .. | .. | .. | .. |
| New Caledonia .. | 2 | .. | .. | .. | .. | .. |
| Norfolk Islands.. | 1 | .. | .. | .. | .. | .. |
| Cocos Islands .. | 1 | .. | .. | .. | .. | .. |
| Rodriguez .. | 1 | .. | .. | .. | .. | .. |
| Batavia .. | 1 | .. | .. | .. | .. | .. |
| Singapore .. | 1 | .. | .. | .. | .. | .. |
| Hong Kong .. | 1 | .. | .. | .. | .. | .. |
| | 175 | 155 | 331 | 36 | 5 | 158 |

NOTE.—Extra 3 p.m. and 6 p.m. reports are also received at the Divisional Offices in each State.

STATIONS WITH INSTRUMENTS.

*Wireless.*

| | |
|---|---|
| Port Moresby (Papua) .. .. .. | 1 |
| Macquarie Island .. .. .. | 1 |
| Adelie Land .. .. .. .. | 1 |
| Ships (average) .. .. .. .. | 9 to 10 weekly |

The barometer readings after being reduced to sea-level, to freezing point, and for standard gravity, are plotted on a separate chart, together with wind direction and wind velocity.

All readings of the same height are then connected up by lines or isobars, thus we have invariably presented on the charts a number of contour curves which represent graphically the different pressures of the atmosphere prevailing over those portions of the earth's surface under review.

Other secondary charts are also compiled for discussion. On one is shown by figures and shading the synchronous weather throughout Australasia, the amount of cloud, rain recorded, and temperatures ; on a second, the variations of pressure for the 24 hours, which indicate in a measure the probable direction of atmospheric drift ; on a third, the variation in temperature for the same interval of time, and this is useful in suggesting the probable route of hot and cold waves.

All these factors are discussed together with the conditions assumed to be normal for the time of the year, and from them the forecast deductions are made.

The degree of accuracy of all forecasts issued averages 88 per cent., and it may be said that material improvement cannot be looked for until the laws which govern the apparent vagaries of movements of cyclones and anticyclones both as to rate and course, and also the, at present, disconcerting fluctuations in pressure which occasionally occur, are determined. The majority of failures in the forecasts may be attributed to want of knowledge on these two points.

Various methods have been adopted to anticipate the divergences from the usual direction of movement of anticyclones and depressions of temperate latitudes, but none have as yet proved satisfactory. It might reasonably be thought that the areas of maximum pressure change would indicate the probable path of advancing centres, or that areas of decided rise and fall in temperature might also give a clue, but the results of extended experiment have proved disappointing.

M. Gabriel Guilbert submitted a method (to the Société Météorologique de France in 1891) of anticipating the approach and progress of depressions by applying the relation of surface winds to the barometric gradient. His theories are strongly supported on parts of the Continent, and appear to have a local application, but they do not seem to apply as satisfactorily in other parts of the world where they have been tested.

Mr. Edward H. Bowie, of the Washington Bureau, has attained a high degree of accuracy in forecasting by a somewhat similar method of his own, but in his case much depends upon the personal equation of the interpreter of the system.

With regard to fluctuations in pressure, we know that such occur by actual translation of the "highs" and "lows," but it is also possible for a super-wave movement to be operating over a relatively stationary lower atmosphere without materially affecting the weather at the surface, and again a dynamical upward and downward action may be a possible explanation.

These suggestions are but tentatively submitted as a desperate attempt to account for certain marked variations of pressure from day to day without a commensurate wind or weather demonstration.

## WINTER ANTICYCLONE.

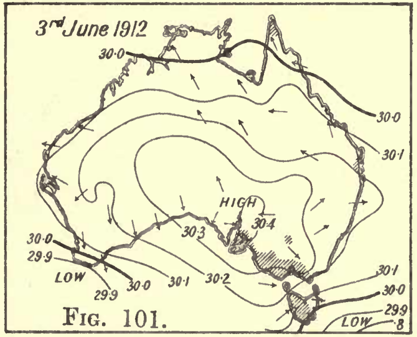


FIG. 101.

## ANTARCTIC DEPRESSION—

Unfavorable to Inland Rains.
No Tropical connection.

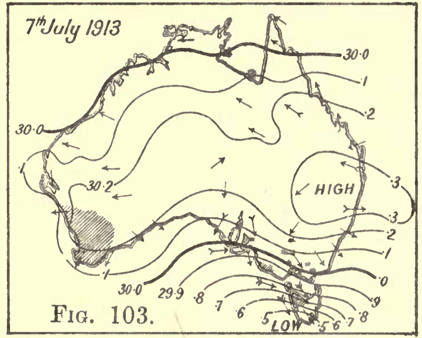


FIG. 103.

## ANTARCTIC CYCLONE—

Passing through Bass Strait.

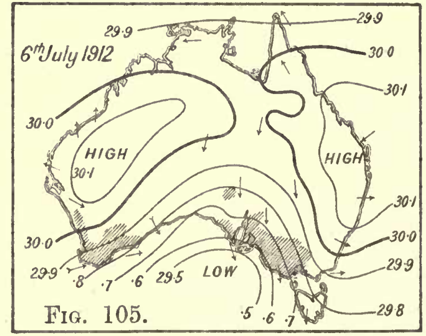


FIG. 105.

## SUMMER ANTICYCLONE.

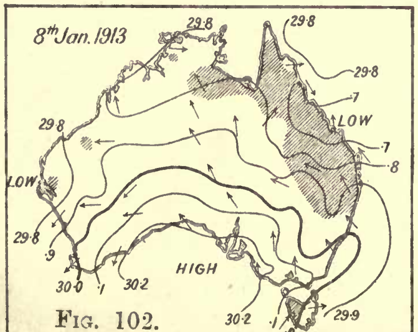


FIG. 102.

## ANTARCTIC DEPRESSION—

With Trough connection with Tropical Low Pressure. Good Inland Rains.

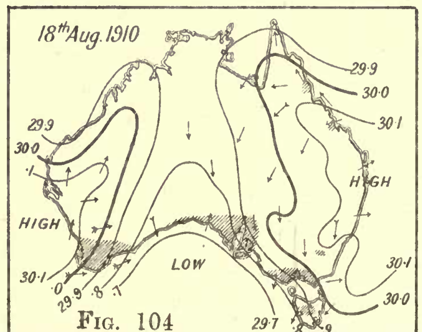


FIG. 104

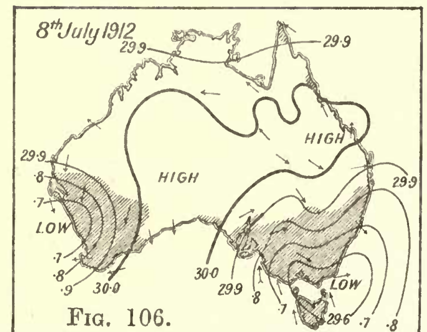


FIG. 106.

## XII.(B).—TYPES OF WEATHER.

The following series of weather charts is given in order to illustrate isobarically and otherwise some characteristic developments in our Australian weather. In connexion with each chart or sequence of charts is given an explanatory note, necessarily somewhat brief, but probably sufficient to enable the salient features in weather progression to be grasped.

### Fig. 101.

*Winter Anticyclones.*—This is a common type of anticyclone in winter. The centre lies near Broken Hill between latitudes 32° and 33°, and anticyclonic weather obtains over almost the whole of the continent. Hence clear skies and dry air, aided by long nights, allow of great radiation of heat from the earth's surface, and frosts are general inland south from the Tropic.

### Fig. 102.

*Summer Anticyclones.*—8th January, 1913, provided an ordinary summer type of anticyclone covering the Bight and lying centrally over a point in about latitude 40° S.—it really passed later over or south from Southern Tasmania. The temperature differences induced by the passage of such systems along the south coast are fairly well illustrated in this case, the southerly winds in its front giving Melbourne a maximum temperature of 65°, and the north-easterly winds in its rear raising the temperature at Perth to 90°.

### Fig. 103.

*Antarctic Depressions unfavorable to good Inland Rains (Winter Type).*—7th July, 1913. This is a typical example of an " Antarctic " with no tropical connexion. The storm has plenty of wind energy, the barometer falling rapidly southwards over Victoria and Tasmania, but the unbroken belt of high pressure lying east and west over the Continent to northward shows that in rain production it is not aided by any flow of air from the tropical belt. The rains resulting from it were practically limited to coastal areas and inland slopes facing the westerly winds.

### Fig. 104.

*Antarctic Depression favorable to Inland Rains (Winter Type).*—18th August, 1910. In this storm the wide trough between 30.0 isobars extending northwards favoured northerly winds and large cloud development as far north as Alice Springs. Rain as far inland as William Creek was recorded next day, and over the whole drainage area of the Darling River within the next two days. Rain production was probably aided considerably by the flow of air southward in front of the trough from well within the tropical belt, the cooling due to increase of latitude favouring condensation.

### Figs. 105 and 106.

*Antarctic Cyclone passing through Bass Strait.*—6th to 8th July, 1912.—An example of an Antarctic cyclone the centre of which passed through Bass Strait. As will be seen, the rainfall was widespread, covering practically all the country south of a line joining Streaky Bay and Brisbane, or not less than 440,000 square miles. On the Victorian highlands falls of over 1 inch were common. The slow rate of movement, about 360 miles per day, is worth noting.

### Figs. 107, 108, and 109.

*Cyclonic Depression Bringing General Rains to Western Australia.*—8th, 9th, and 10th July, 1912.—The great cyclonic depression shown entering Western Australia on the 8th July, between Perth and Geraldton, was probably of oversea tropical origin, but whether this was so or not it not only brought a splendid general rain to all Western Australia south of the Tropic, but, maintaining a trough connexion with the tropical low-pressure belt as it moved eastward, by the 13th, it gave much rain to a long strip of inland country extending from the Territory to Northern New South Wales, as well as to South Australia and Victoria.

### Figs. 110, 111, and 112.

*Summer Monsoonal Rains.*—6th to 18th January, 1913. Though the rainfall indicated on this chart is unusually widespread and heavy over Northern Australia, it occurs in connexion with a typical monsoonal depression, and there is no reason for regarding it as caused in any other way ; that is, there is no necessity for assuming the intrusion of a tropical disturbance or any great atmospheric movement southwards. It was, however, preceded by the formation of a low pressure focus over the north-western interior of Western Australia and followed by a concentration of the rainfall over Eastern Queensland, where another slight low pressure focus was formed. The latter is shown by the chart of the 8th.

# CYCLONIC DEPRESSION ENTERING BETWEEN CAPE LEEUWIN AND SHARK BAY BRINGING GENERAL RAINS TO WESTERN AUSTRALIA.

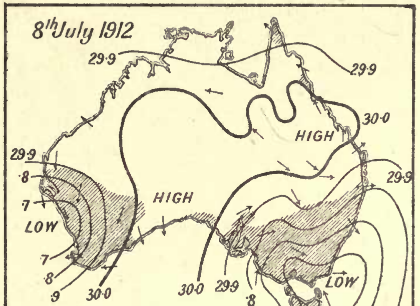


FIG. 107.

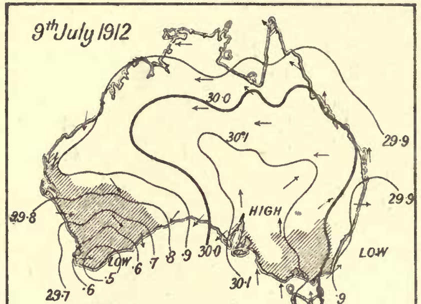


FIG. 108.

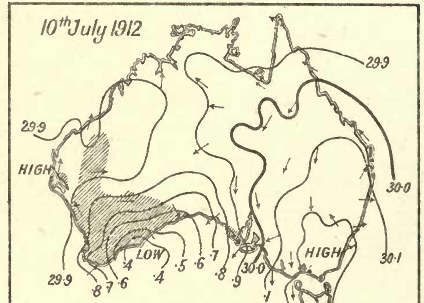


FIG. 109.

# SUMMER MONSOONAL RAINS—NORTHERN AUSTRALIA.

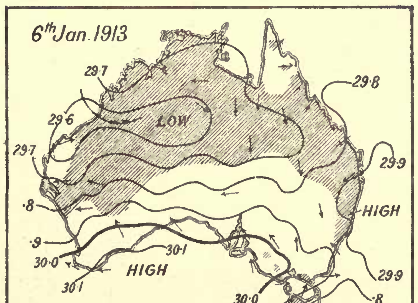


FIG. 110.

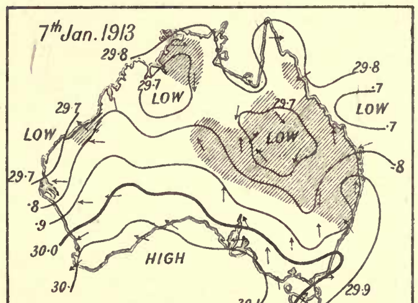


FIG. 111.

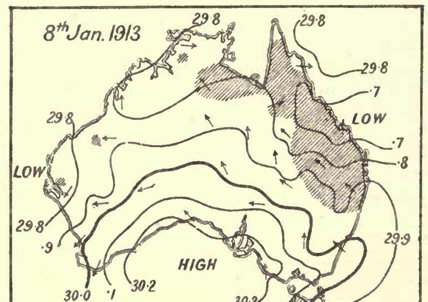


FIG. 112.

NOTE.—Shading shows where rain fell during previous 24 hours. Wind direction shown thus ⟶ Strong winds ⤜⟶

| ANTARCTIC CYCLONE— | INLAND WINTER RAINS— | TROPICAL RAIN STORM— |
| --- | --- | --- |
| Passing over Inland Victoria, with general Rains. | Of Tropical origin and Cyclonic ending. | Moving from the Territory Southward into South Australia. |

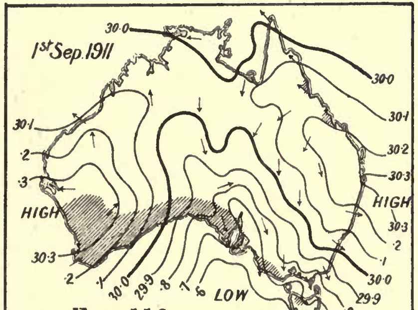


FIG. 113.

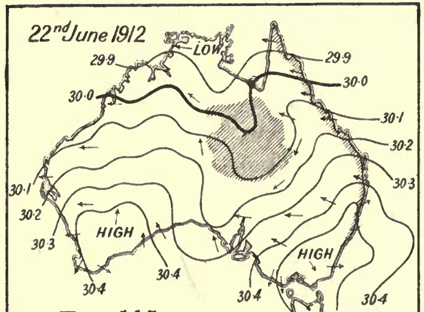


FIG. 115.

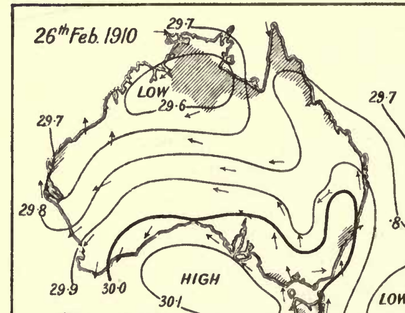


FIG. 117.

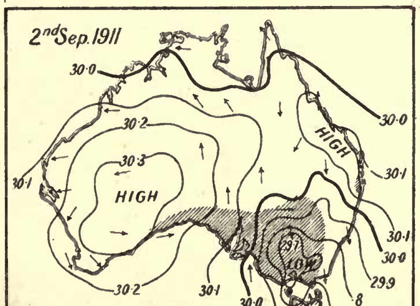


FIG. 114.

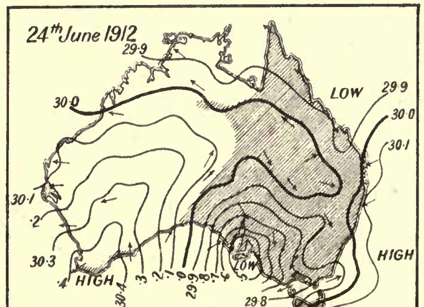


FIG. 116.

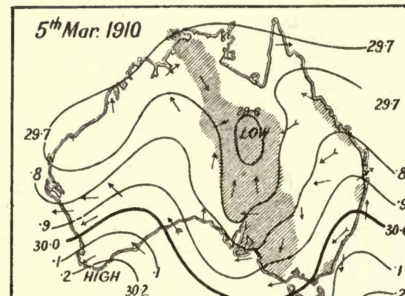


FIG. 118.

NOTE.—Shading shows where rain fell during previous 24 hours. Wind direction shown thus ⟶ Strong winds ⟶

### Figs. 113 and 114.

*Antarctic Cyclone passing inland.*—1st and 2nd September, 1911. The heavy and extensive inland rain which accompanied this inland cyclone was the only good spring rain experienced in 1911, and was the salvation of the crops over South Australia, Victoria, and much of New South Wales. The chart of 1st September shows it as an ordinary Antarctic disturbance, but with an exceptionally good trough extending northwards in front of which there was a wide and unbroken flow of northerly winds from the Gulf of Carpentaria into South Australia and Victoria. It is possible that the condensation induced by the transfer of such a large body of air into higher latitudes was mainly responsible for the cyclonic development and heavy rains.

### Figs. 115 and 116.

*Inland Winter Rains of Tropical Origin and Cyclonic ending.*—During June and July, 1912, no less than four rain storms originated in the northern interior of the continent, two of which developed enormously and gave heavy rains to the whole eastern half of the continent. The charts of 22nd and 24th June show stages in the barometric development of the second of these storms, warning of which was first given on the 21st by the occurrence of thunderstorms in the far north-west of Queensland. Next day these were occurring over a much greater area, extending northwards beyond Powell's Creek and southwards to Broken Hill, the isobars at the same time dipping southwards towards the Bight, where previously barometers had read up to 30·5 inches. During this and the next day its rain production was at its maximum. By the 24th, a very symmetrical and fairly intense cyclone was centred near Adelaide. This afterwards rapidly lost energy both as regards pressure and rain production, and moved slowly eastwards over Victoria.

It is worthy of note that in this case, as in that of many other storms of tropical origin, the cloud and rain development were always in advance of the isobaric showing clearly the convectional origin of the cyclone which followed.

### Figs. 117 and 118.

*Tropical Rain Storm moving Southward from the Territory into South Australia.*—Examples of this type of storm are not very numerous, but the fact that they occur almost as readily in the winter as in the summer months shows that they are not in any sense monsoonal. Perfect examples of this occurred on the 31st July, 1908, and 6th–8th June, 1907. They all gave splendid rains over the central parts of the continent. That of 26th February—5th March, 1910, was, however, the most remarkable in that and in every other respect.

On the 25th February heavy rain was general as far south as Powell's Creek, and this was accompanied by the formation of a definite low-pressure centre south from Port Darwin. This slowly moved due southwards, accompanied by a tremendous rainfall amounting at many inland stations to very nearly the annual average. By the 5th March, South Australia was deluged, and the storm, which then became very definitely cyclonic, moved off over Victoria towards the S.E., giving rainfalls in low-lying plain country of 4 or 5 inches, and up to 12 inches amongst the mountains.

### Figs. 119 and 120.

*Willy-willy affecting Coastal Parts only.*—The tropical cyclones, which during the summer half of the year are occasional visitants to the north-west coast of West Australia and known there as "willy-willies," generally follow paths tending to carry them inland. But in most cases their identity is then speedily lost, barometric intensity and wind energy disappearing and the storm becoming merged into an ordinary "monsoonal dip." In a few cases they keep out to sea, and, moving southwards, may even round Cape Leeuwin. In the case of the very violent one shown centred near Onslow on the 7th February, 1911, apart from the heavy local coastal rains of the 6th and 7th, the rest of the State did not benefit, and the storm either moved off seawards or broke up altogether.

### Figs. 121 and 122.

*Willy-willy moving Inland.*—On the 19th January, 1909, is another willy-willy not quite so intense as that of the 7th February, 1911, but occurring with almost the same general pressure distribution. Yet this one moved inland, and by the 21st January had reached the Murchison gold-fields, having lost but little of its intensity, and bringing very heavy rain to the Murchison and Northern Coolgardie gold-fields. It then moved slowly eastward across the continent with diminished intensity, but still accompanied by rain even to the Queensland coast.

### Figs. 123 and 124.

*Gales through Bass Strait.*—Westerly gales naturally occur whenever the barometric fall southwards is rapid and the isobars lie approximately east and west through the strait. The most frequent cause of this is the passage of an Antarctic low, not only intense but on a large scale over Southern Tasmania or the ocean waters south of it. Such is the storm shown on the charts of 13th and 14th September, 1912. The chart of the 13th shows what may be described as a "square-headed" low, the squareness being due to the formation of a second trough closely following the first. Such a development in an energetic disturbance invariably means severe weather, especially along the coast line, with hail showers and not infrequently thunder. The weather of the 13th was no exception. The first eighteen days of this month were exceptionally boisterous, owing to the prevalence of this type of storm.

| WILLY WILLY RETURNING OCEANWARDS. | WILLY WILLY MOVING INLAND. | WESTERLY GALES THROUGH BASS STRAIT. |
|---|---|---|

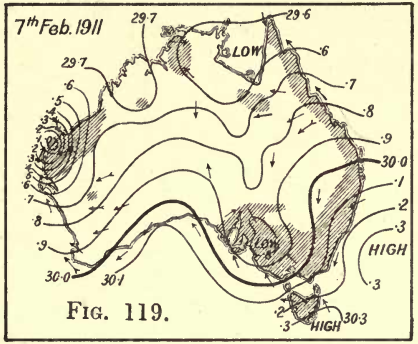


FIG. 119.

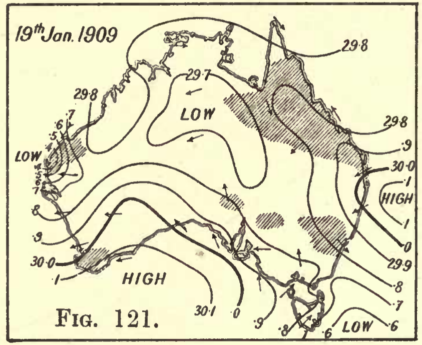


FIG. 121.

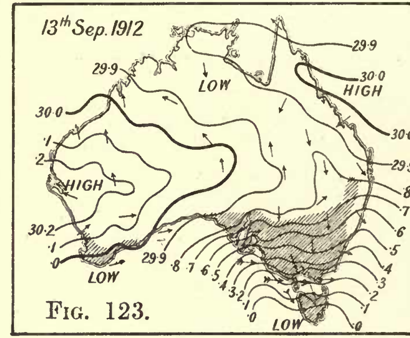


FIG. 123.

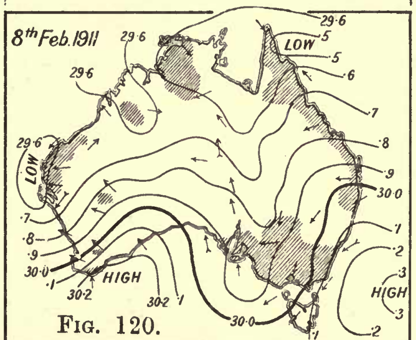


FIG. 120.

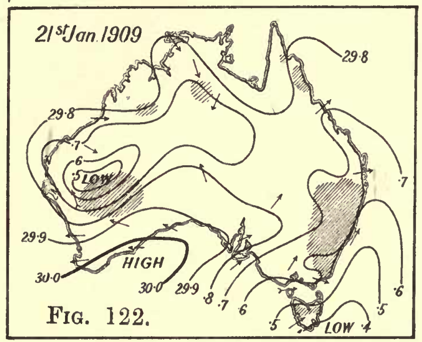


FIG. 122.

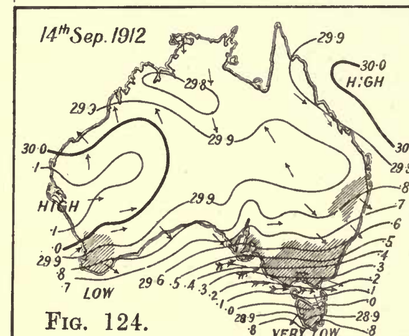


FIG. 124.

NOTE.—Shading shows where rain fell during previous 24 hours. Wind direction shown thus ⟶ Strong winds ⟿

## EASTERLY GALES THROUGH BASS STRAIT.

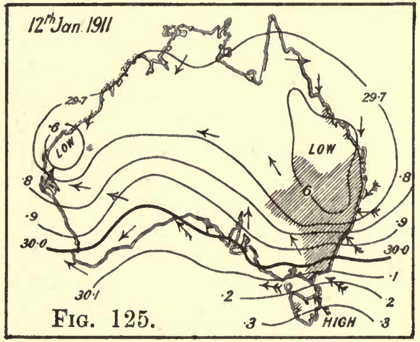


FIG. 125.

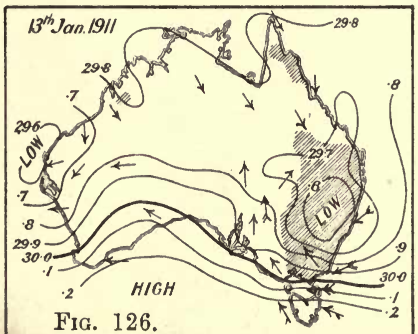


FIG. 126.

## ANTICYCLONE FORCED SOUTHWARD OVER TASMANIA BY CYCLONE OFF NEW SOUTH WALES COAST.

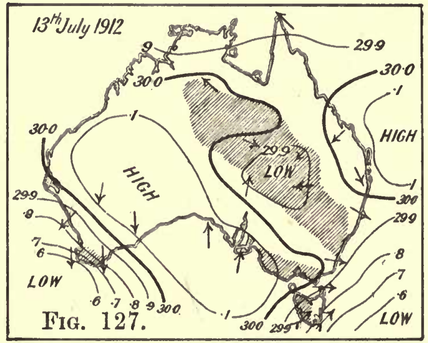


FIG. 127.

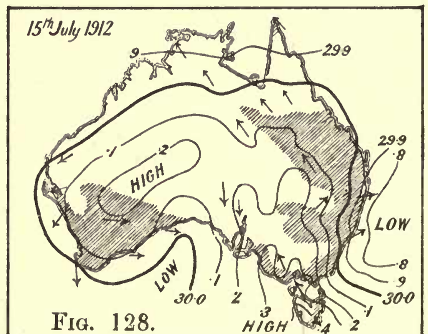


FIG. 128.

## COLD SNAP, SOUTH-EAST AUSTRALIA.

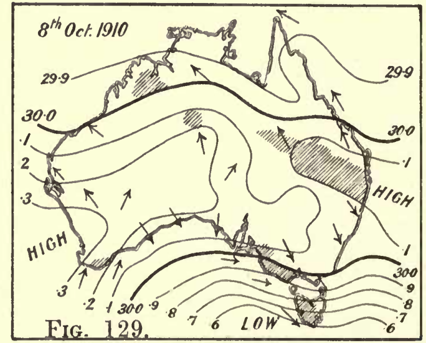


FIG. 129.

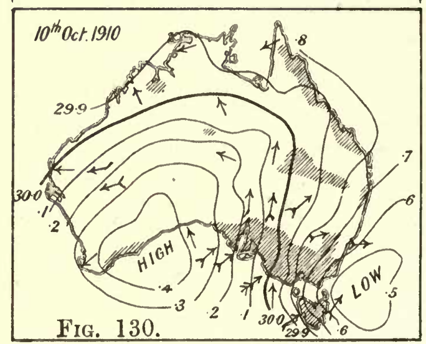


FIG. 130.

NOTE.—Shading shows where rain fell during previous 24 hours. Wind direction shown thus ⟶ Strong winds ≫⟶

### Figs. 125 and 126.

*Easterly Gales through Bass Strait.*—These also occur occasionally though only very rarely, and, of course, when the barometric gradient is reversed, the most common case being an intense monsoonal cyclone or dip over New South Wales opposed by a strong anticyclone over Tasmania. 12th and 13th January, 1911, provided a case of this kind, the weather in Bass Strait and even in Port Phillip being exceptionally severe. Very rough weather also prevailed on the New South Wales coast.

### Figs. 127 and 128.

*Anticyclone forced Southwards over Tasmania by Cyclone off New South Wales Coast.*—The warm waters off the east coast of Australia are very favorable to vigorous cyclonic development, and many depressions reaching these waters after a journey across the continent, during which their barometric effect was very feeble, give rise to great displays of energy. But whatever their origin, whether it be directly from the tropical seas to northward, or monsoonal depressions inland, or even from the heads of Antarctic disturbances, they show a marked tendency to cling for days at a time to the coastal waters. This appears to have a twofold effect upon the following anticyclone—(*a*) it is partly forced southwards ; (*b*) it is merged into a semicircular high-pressure ridge built up on its southern sides by the cyclone and extending from southern New Zealand across the ocean to Tasmania, and then north-west or north towards the Northern Territory or the Gulf of Carpentaria. The cyclone shown on the chart of 15th July, 1912, apparently originated near Alice Springs on the 12th, where thunderstorm rains were then falling and evidence of the beginning of a separate low centre being given, became cyclonic off Port Macquarie on the 14th, and held the "High" in the position shown for four days (14th to 17th inclusive).

### Figs. 129 and 130.

*Cold Snap (South-eastern Australia).*—The cold weather of 9th and 10th October, 1910, was phenomenal. It began almost simultaneously in South Australia and Victoria on the 9th, when heavy snowfalls during the afternoon were almost general from Spencer Gulf to Gabo Island.

The chart of the 10th, with its cyclonic centre off Gabo Island and steep gradients, indicates very unsettled and rough weather conditions, which were sufficiently illustrated in Melbourne during the early morning by heavy hail storms, vivid lightning, and sharp peals of thunder. Moreover, the great length of north and south isobars which overlay Eastern Australia and extended through at least 30° latitude favoured great transference of cold air from Antarctic seas, even into tropical Queensland. It is doubtful, however, if it can be taken as sufficient demonstration of the cause of the heavy snowfalls and exceptional cold, the snowfall and greatest drop in temperature in Victoria taking place in the afternoon of the 9th, when winds were still westerly. The minimum at Adelaide fell to 36·8 on the night of

the 9th, about the lowest on record there for October. Probably the real significance of the phenomenon lies in the fall of pressure which took place from the southwards between the 8th and the 10th, causing the 30·0 isobar which lay east and west from Cape Borda to Gabo Island on the 8th to turn as it were upon an axis so as to lie north and south less than 48 hours later. Over Northern Victoria the barometer fell from 30·1 to 29·7 within 24 hours from this cause, that is, to some impulse apparently coming from due south. The interesting question then arises, "To what extent was the cold and storm production generally due to rarefaction at the rain-producing levels ?" The similarity between the phenomena of this storm and that of 28th September–1st October, 1908 (Figures 137–139) is worth noting. An examination of five other cases of unusual cold with snowfall in Melbourne shows this tilting of the rear isobars of the "low" causing them to lie north and south to be a common feature. This involves a displacement of the following "high" centre from a normal position over South Australia to one several degrees further south, and the "high" is always an intense one.

# PROLONGED HOT SPELLS—SOUTH-EASTERN AUSTRALIA.

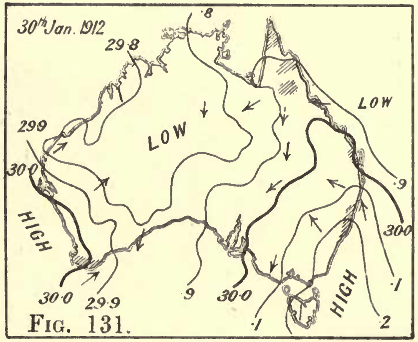


Fig. 131.

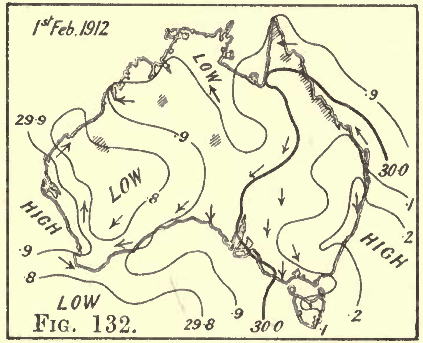


Fig. 132.

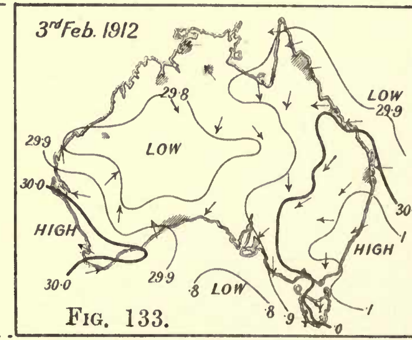


Fig. 133.

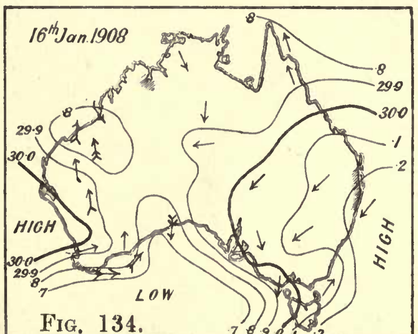


Fig. 134.

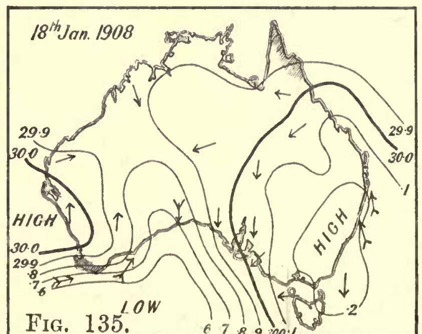


Fig. 135.

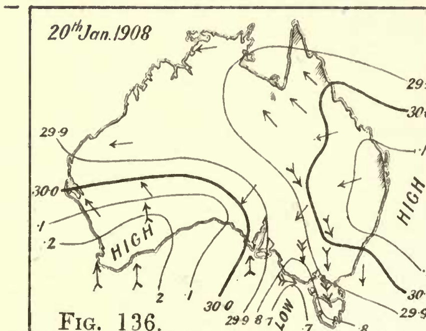


Fig. 136.

Note.—Shading shows where rain fell during previous 24 hours. Wind direction shown thus ⟶ Strong winds ⟶

### Figs. 131 to 136.

*Hot Spells in Southern Australia.*—In the southern parts of the continent or, say, within 200 or 300 miles of the south coast-line, spells of heat unpleasantly great are usually of short duration. The immediate cause is a low-pressure trough connected with an Antarctic disturbance, and as the average rate of summer Antarctics is about 800 miles per day the northerly winds in advance of the trough rarely last more than 24 hours. This is more expecially the case on or near the coast-line; the further inland we go the longer the preliminary period during which light variable or easterly winds preceding the true northerly induced by the trough are allowing an accumulation of heat. But occasionally even coastal towns are subjected to hot spells lasting several days. The prime factor for this is always a stationary anticyclone centred over Tasman Sea, but with its western slopes overlying eastern and south-eastern Australia. This usually goes with some slow-moving monsoonal depression over the western interior of the continent, or an Antarctic disturbance which fails in its advance eastwards. The real problem here is the cause of the stationary condition of the anticyclone. This set of maps provides reason for thinking that it may be the same as has already been noted in connexion with the dry winter of 1899, when cyclones off the east coast held back or built up the following anticyclones so as to form a semicircle of high pressures on their south-eastern and south-western to north-western boundaries. In this case there is evidence that a tropical cyclone for some days was following the usual parabolic course—not near the east coast, but away to the north-east—in the neighbourhood of New Caledonia. Such a course would certainly tend to maintain high pressure over Tasman Sea, and it may be that this is the usual cause of the phenomenon under review. The maximum temperatures in Melbourne for the five days 30th January–3rd February, 1912, were 96·4°, 102·6°, 106·5°, 105·9°, and 102·5° respectively.

Much the same operating factors appear to have been at work during the still more severe and, in Melbourne, record spell of heat from 15th to 20th January, 1908, the successive maxima at the Weather Bureau being 102.0°, 106·7°, 109·3°, 104·1°, 105·7°, and 107·5°. The charts for this period also show evidence of the existence of a very persistent tropical low-pressure system operating for some days away to the north-east beyond the high over Tasman Sea. This is most marked from the 16th to the 19th, when barometers were falling over Norfolk Island and the extreme north of New Zealand, and rising over eastern New South Wales and Victoria. On the 20th, when the tropical low was moving off, as shown by pressures rising again at Norfolk Island, the centre of the "high" moved northwards, allowing the trough of a slight Antarctic to move eastwards along the south coast of Victoria, thus bringing the much desired cool change. The charts for the 16th, 18th, and 20th illustrate the changes noticed on this occasion.

### Figs. 137, 138, and 139.

*East Coast Cyclone of Antarctic Origin.*—The appearance on the coast of New South Wales of a cyclone owing its origin to the passage of an Antarctic disturbance is a somewhat irregular phenomenon, being of comparatively frequent occurrence in some years, or groups of years, and rare in others.* The case here shown is a fairly typical one. On the 26th September, 1908, an ordinary Antarctic "Λ" depression lay over the Bight, while a high pressure system covered the eastern half of the continent. By the 28th, the low had passed Gabo and extended well up the New South Wales coast-line, the southerly winds in rear of it being very cold, with showers and squally weather. By the 30th, the Antarctic disturbance proper had passed completely away, but an elliptical depression was left over Tasman Sea, the coastal weather being still dominated by southerly winds, and very cold and wet. Snow fell extensively over the mountains in New South Wales. Next day the circulation was definitely cyclonic, and the weather warmer owing probably to all southern connexion being severed by high pressures forming to southward over Tasman Sea. The storm centre then moved off in a south-easterly direction.

### Figs. 140 and 141.

*East Coast Cyclone of Inland Origin.*—A typical example of this happened on the 18th January, 1911. On the previous day a very pronounced monsoonal trough extended from Western Queensland into Victoria, the line of lowest pressures being slightly below 29·8 inches. Moderate to heavy rain fell during the next 24 hours in front of this line, and on the 18th, the eastward advance of the trough carried it over the New South Wales coastline, where pressures promptly fell some two-tenths of an inch and the air circulation became of the cyclonic type. The fall in temperature along the New South Wales coast produced by its rear circulation was very slight.

---

* The fact that East coast cyclonic storms of antarctic origin are, for long periods, rare, helps to emphasize the very abnormal character of the weather of the latter half of 1905, in which no less than eight of these storms occurred. This is one of the many instances of definite tendency for special weather types to recur in certain seasons, thus giving to at least some seasons a kind of individuality. As the latter half of 1905 was, in Melbourne, the coldest on record, two abnormalities at any rate are in agreement.

# EAST COAST CYCLONE OF ANTARCTIC ORIGIN.

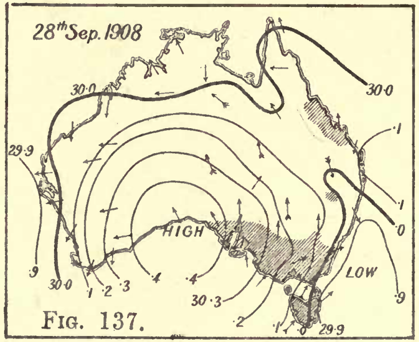


FIG. 137.

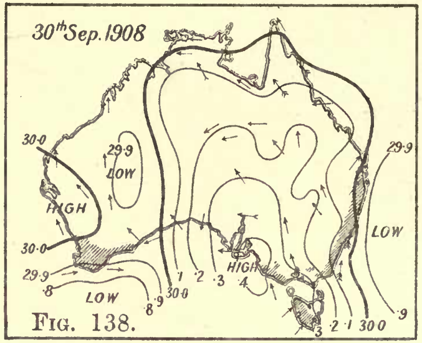


FIG. 138.

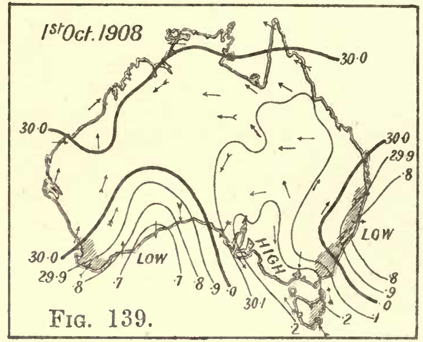


FIG. 139.

# EAST COAST CYCLONE OF INLAND ORIGIN.

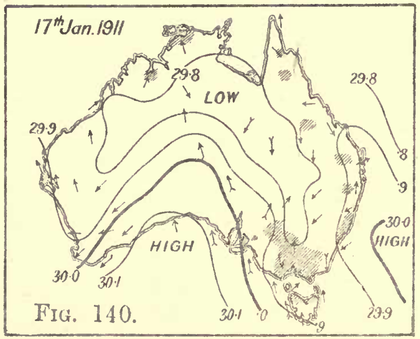


FIG. 140.

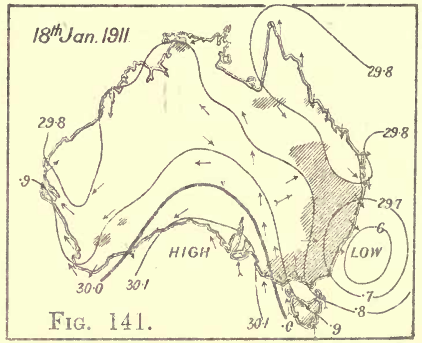


FIG. 141.

NOTE.—Shading shows where rain fell during previous 24 hours. Wind direction shown thus ⟶ Strong winds ⤜⟶

## EAST COAST CYCLONE OF OCEANIC ORIGIN.

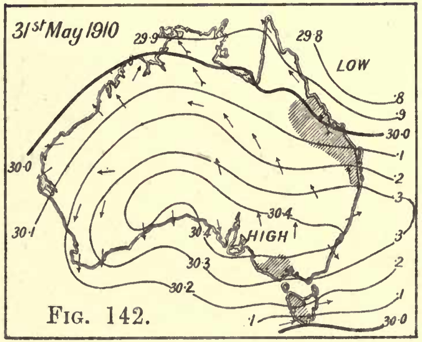


FIG. 142.

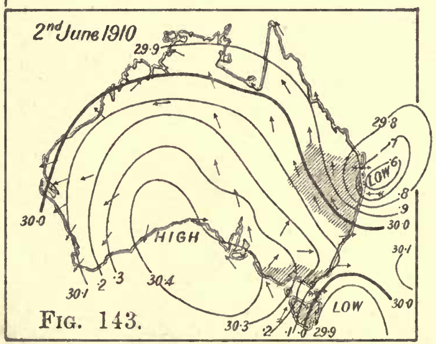


FIG. 143.

## TROPICAL CYCLONE, NORTH QUEENSLAND.

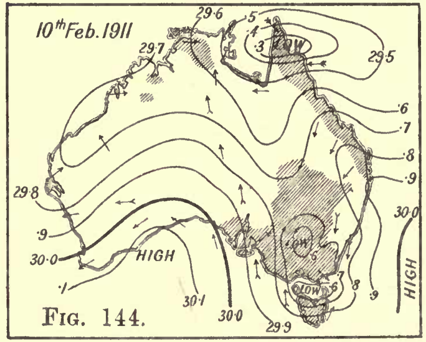


FIG. 144.

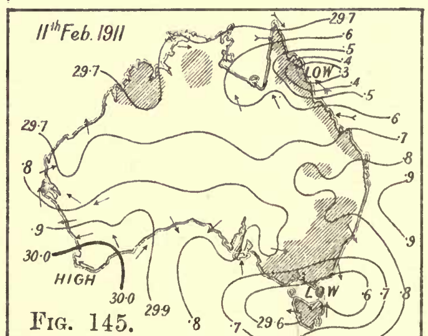


FIG. 145.

## DEVELOPMENT OF MONSOONAL TROUGH.

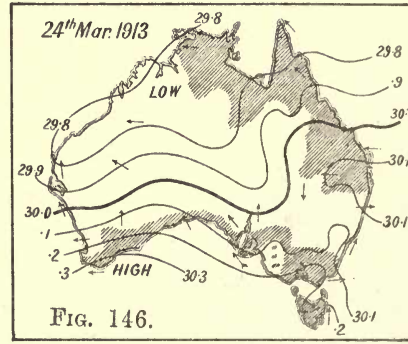


FIG. 146.

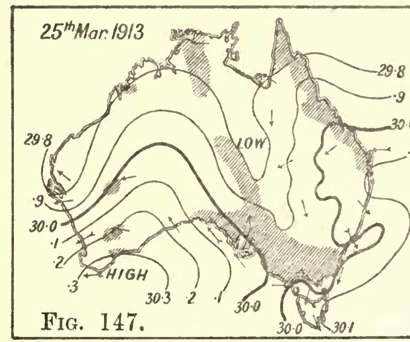


FIG. 147.

NOTE.—Shading shows where rain fell during previous 24 hours. Wind direction shown thus ⟶ Strong winds ⇢

### Figs. 142 and 143.

*East Coast Cyclone of Tropical Oceanic Origin.*—31st May–2nd June, 1910. This storm was first definitely indicated on the 31st May by falling barometers over New Caledonia and the North Queensland coast, with rain setting in rather extensively over the Central portions of Eastern Queensland. During the next 24 hours heavy rains fell on the coast south from Townsville, and moderate amounts were recorded generally over the south-eastern half of the State. On 2nd June, a definite cyclonic storm was centred off Brisbane immediately south of which some tremendously heavy rain fell. Cleveland had no less than 11·20 inches in the 24 hours. The winds though strong do not seem to have been of exceptional force. The storm continued its southward course for another day, bringing rain to the eastern parts of New South Wales, then moved off towards New Zealand. These storms may occur at any season, and are felt most severely along the coast-line between Brisbane and Sydney, where they develop a wind force and coastal rain production much beyond what their previous history while approaching oversea from the north or north-east would suggest. The steep barometric gradients induced on their south-west quadrants by anticyclonic conditions advancing eastwards over southern Australia probably assist to some extent.

### Figs. 144 and 145.

*Tropical Cyclone, North Queensland.*—10th and 11th February, 1911. Storms of this type in North Queensland are confined in time almost entirely to the summer months, December to April inclusive. They usually strike the coast-line some few degrees further south than the position shown on the 10th, in which case they approach the coast from some point north of east preceded by overcast skies, heavy rain, falling barometers, and freshening winds from between S.S.E. and east. A heavy sea swell, the direction of which is a good index of the position of the storm centre, usually precedes the hurricane winds by some hours.

The storm shown here appears to have developed cyclonically from a depression with very slight gradients which lay over the Gulf of Carpentaria for two or three days previously. As the latitude is but little more than that usually assigned for the origin of tropical cyclones it is probable that the genesis of one is here represented. The chart of the 11th shows the centre further south, about Cardwell; next day it was just inland from Mackay with diminished energy, and it soon after lost its identity altogether. These cyclones usually develop winds of hurricane force between Cooktown and Townsville severe enough at times to wreck buildings. In this case, however, not much damage appears to have been done by wind, but very heavy rains fell—Port Douglas recording 11·88 inches in the 24 hours ending 9 a.m. on the 11th, and the rivers were flooded. These storms are seldom or never experienced with any severity on the New South Wales coastline.

### Figs. 146 and 147.

*Development of a Monsoonal Trough.*—24th and 25th March, 1913. The way in which what appears to be an ordinary monsoonal dip in the isobars may under convectional action develop a barometric trough cutting the high to southward in two and joining the tropical and Antarctic low pressure belts is well shown here. Such an occurrence is practically always associated with rain, frequently heavy inland, and this, contrary to the usual experience inland, may be accompanied by southerly winds. The most reliable indications of rain in such cases are widespread cloud formation in the "dip" and a flow of upper air, as shown by the movements of cirrus or other high-level clouds over Victoria from some northerly point.

### Figs. 148, 149, and 150.

*Great Dust Storms.*—11th–13th November, 1902. The raising of dust in Australia in summer time can hardly be said to require any special type of weather. That it be windy is usually sufficient. There are, however, seasons in which the production of dust becomes specially easy. Such was the spring of 1902, when the rainfall inland over large areas was so scanty that the surface soil once broken never became sufficiently compacted again by moisture to prevent strong winds, especially those of variable direction, from carrying it away. Many carefully worked fallowed lands in the northern parts of Victoria were practically swept bare of the loose soil mulch which had been so laboriously prepared by cultivation to conserve moisture and provide plant food for the next year's crop. Many a boundary fence was obliterated and lane filled to a depth of several feet by wind borne sand and loam during this year. In New South Wales the same occurred over large areas of purely pastoral country.

The charts for 11th, 12th, and 13th November, 1902, show all that barometer readings can tell us of the genesis and development of the worst of these dust raising storms. The morning of the 12th in Melbourne was beautifully fine, calm, and pleasant, the sky only partly covered by thin cirrus clouds moving from W.N.W. About 1 p.m. the calm was broken by a violent burst of northerly winds, which an hour or two later gave place to almost equally violent westerlies, and these to fierce north-westerly squalls a little later. The dust was at times suffocatingly dense, and the upper air was so loaded with it that the sun was rarely visible. In the country the effects were much more marked. At many inland towns the darkness produced almost equalled that of the blackest night, and in the houses nothing could be done without lamps or other means of lighting. Added to this were some phenomena of an even more terrifying character. At Boort and in some parts of the Riverina the storm was accompanied by a sort of globular lightning, "fireballs" were seen falling on the fields and roads, and scattering the earth. As these electrical phenomena were produced in a dry atmosphere the assumption is that they were due in some way to friction between dust particles.

The weather charts themselves are most interesting, and show that atmospheric changes and movements of a most unusual character were in progress. The chart of the 10th shows unusually quiet weather over the continent, the

# DUST STORMS.

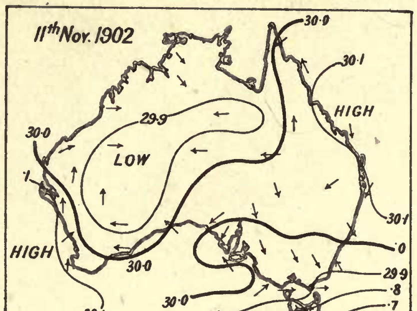


FIG. 148.

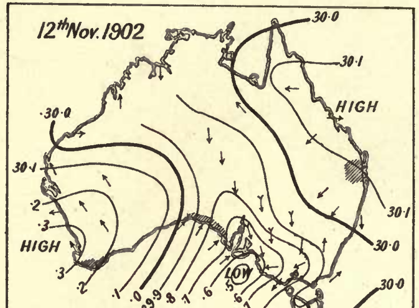


FIG. 149.

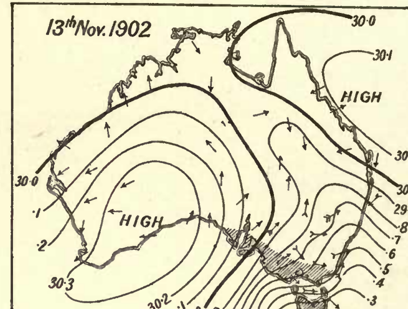


FIG. 150.

# FOGS IN MELBOURNE.

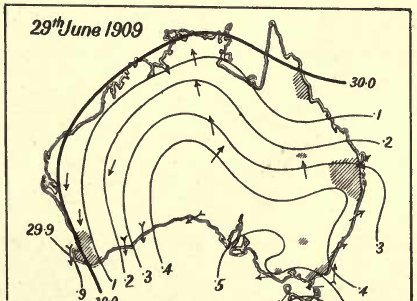


FIG. 151.

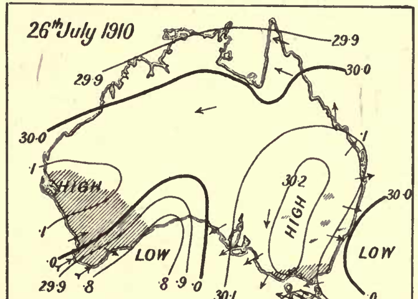


FIG. 152.

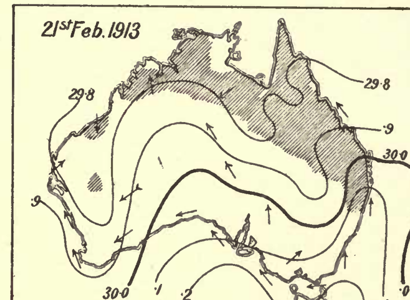


FIG. 153.

NOTE.—Shading shows where rain fell during previous 24 hours. Wind direction shown thus ⟶ . Strong winds …

only low-pressure system being an Antarctic passing eastward over and south from Tasmania, and a large monsoonal depression covering the western and northern interior of the continent. The two were separated by a large area of "flat" barometric pressures, never varying much from 30·0 inches. This is, of course, known to be rather favorable to the development of local squalls and thunderstorms inland, but these do not seem to have occurred, at all events in any isolated fashion, as no rain fell in New South Wales and very little in Victoria. On the morning of the 12th a "low," apparently cyclonic, was centred off Robe, where the barometer reading had fallen during the 24 hours from 29·99 to 29·52, nearly half-an-inch. The formation of this storm centre seems to be intimately related to the monsoonal depression of the preceding day, as a well-marked trough along the front of which northerly winds blow runs well beyond Alice Springs. These winds would necessarily be hot—at 9 a.m., 97° at Alice Springs; 95° at Farina; 90° at Broken Hill, &c.—and the rapid fall of pressure to southward producing steep gradients made them strong. Next day's chart shows the intensification still in progress. Gradients were very steep, especially in rear of the trough, the fall in pressure from Adelaide to Southern Tasmania being exactly 1 inch. Hence wind strength did not lessen at all with change of direction as the trough passed. All the conditions necessary to maximum dust production were, therefore, present—(1) preceding drought; (2) great heat; (3) strong and variable winds; (4) no rain with the storm itself.

Three months later, on the 14th February, 1903, a very similar storm occurred, dust being carried upwards to such an extent that the clouds of alto-cumulus level became of a curious copper colour, and the rain which afterwards fell was at first loaded with dirt. In many parts of Victoria remote from the inland plains the surface of the ground took on a different tint owing to the foreign matter deposited upon it. The amount of surface soil transported in this way during this summer was undoubtedly enormous. Another effect of these wind storms was a redistribution of plant life. In the Mallee the number of new varieties of grasses and small flowering plants springing up after the next winter's rains was a matter of frequent comment.

## Figs. 151, 152, and 153.

*Fogs.*—Although fog is not usually regarded as one of the most important meteorological phenomena, its occurrence often has a very practical bearing upon the affairs of life. In the country, and especially among the hills, it may provide no inconsiderable portion of the moisture supply, while at other times its formation when destructive frosts are threatened is very welcome. In large cities its value is not so apparently positive, and from some aspects becomes very decidedly negative. This is seen in its effect upon the speed of traffic and consequent hindrance to business. What its value may be in providing excuses for tardy arrivals in public offices is, of course, another matter.

Fogs are very local phenomena, the general causes in the way of pressure, distribution, &c., which favour their development in one locality not being at all effective in others. One factor must, of course, be present in every case; that is the presence of water vapour in the lower stratum of air in

sufficient quantity to produce saturation before the cooling by radiation or otherwise has reached its limit. Cooling by radiation being the most frequent cause of fog, it follows that the sky should be clear, and this most frequently happens during the passage of an anticyclone. But the air is then usually very dry, so much so that under ordinary circumstances inland in the winter months frost is the more probable result. The water vapour necessary for fog production is most likely to be present inland when a clear, calm night follows rain, and especially when the high-pressure system forms a wedge separating two "lows."

Fogs in Melbourne are most frequent in the early winter months, May–July. The conditions most favorable for their production are well illustrated by the three charts shown. It nearly always happens that the anticyclone is centred to southward. The effect of this is obvious. The gentle outflow of air from the high along the earth's surface reaches Melbourne from points between south and east, having just passed over a water surface, and so carrying a fair amount of moisture. The fact also that a cyclonic depression has very frequently been operative just before off the New South Wales coast and driven masses of humid air into Bass Strait would aid in this result. In connexion with this latter factor the influence of the mountains or hilly country stretching southwards from the Yarra sources into South Gippsland cannot be ignored, inasmuch as it causes the dissipation of the clouds of lower levels coming from the east or south-east, and thus aids in producing the required clear night sky over Melbourne. A very favorable type is that of 21st February, 1913. The tendency towards a tropical "dip" in the isobars seems to indicate sufficiently humid conditions inland. One of the densest fogs ever experienced in Melbourne was on the night of the 26th July, 1910. In this case heavy rains had just fallen over Gippsland, and the high is but the separation between two "lows." During very dense fogs the air movement is often from the north-east. This is not necessarily the direction of air movement which preceded the fog formation, but it helps to illustrate the usually small convectional action with light north-easterly breezes, as was noted previously in a paper dealing with observations upon the amount of dust ordinarily suspended in the atmosphere of Melbourne.

MARONG TORNADO.
(VICTORIA.)

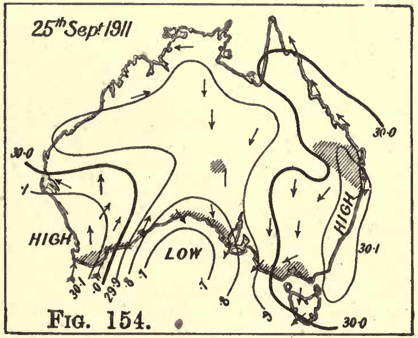


FIG. 154.

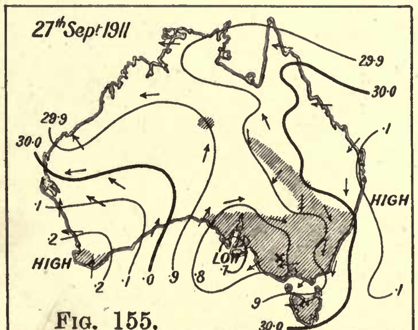


FIG. 155.

TORNADO-LIKE WINDSTORMS PRECEDING
THE GEMVILLE TORNADO.

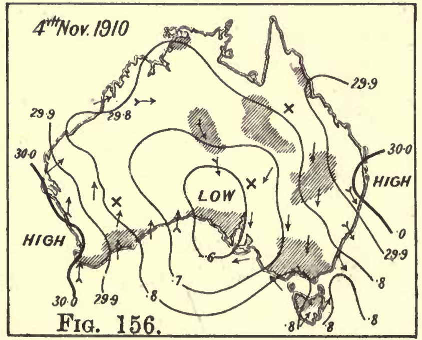


FIG. 156.

GEMVILLE TORNADO.
(NEW SOUTH WALES.)

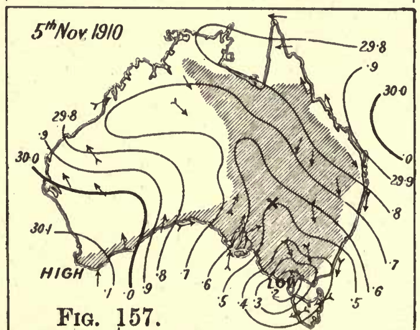


FIG. 157.

AVENEL TORNADO (?)
(VICTORIA.)

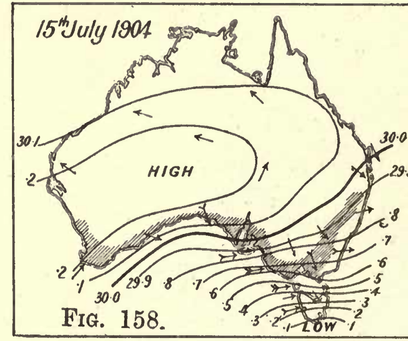


FIG. 158.

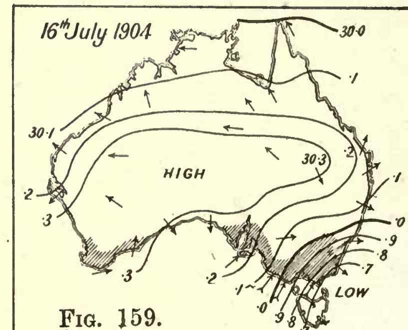


FIG. 159.

NOTE.—Shading shows where rain fell during previous 24 hours. Wind direction shown thus ⟶ Strong winds ≫⟶

## TORNADOES.

### FIGS. 154 TO 159.

The name "tornado" is given to an excessively violent and destructive wind storm affecting only a narrow strip of country, and producing its destructive effects, not by a straight blow, but by air in rapid rotation, as in a whirlwind. From the latter, which is relatively insignificant, the tornado differs essentially, as it does also from the vastly wider cyclone, though the terms are often confused.

The tornado is always associated with thunder and hail storms of extremely violent type. If we regard a thunderstorm as due to the uprushing of a column of air, from, say, the 4,000 to the 20,000 or even 30,000 feet level this giving rise to, and in turn being maintained by, the condensation of aqueous vapour, with the resulting phenomena of rain, hail, electric discharge, &c., and this column of air to take on a rapid spiral movement, which it naturally does, then the downward extension of this spiral movement to the ground provides the tornado. It is in respect to this thunderstorm origin that it differs from a whirlwind, the latter usually originating at ground level and not rising high enough to cause condensation in the very dry, hot air in which it occurs. The radius of action of the tornado may not be much greater than the few yards covered by an ordinary whirlwind, and rarely exceeds one-fourth of a mile, but what it lacks in area it more than makes up in intensity. From the cyclone it differs in the area affected, but, nevertheless, it is not to be regarded as a miniature cyclone. The tornado is a part of one thunderstorm; the cyclone is a vastly wider circulation of the air set in motion, at all events when of tropical origin, by the prevalence over a considerable area of the earth's surface of conditions which may be incidentally indicated by the occurrence of thunderstorms and even tornadoes in isolated parts of it. Some of the primary essentials to these conditions would be heat and atmospheric humidity above normal. It may be suggested, too, that the vertical temperature gradient would provide a means of definitely separating the two. In the tornado or thunderstorm the rising air must at any level, except possibly near the top, be warmer than the surrounding air at the same level, while above the cyclone the air soon becomes actually colder than at the same levels in the surrounding anticyclones. This is, of course, only another way of saying that a steep vertical temperature gradient is favorable for the occurrence, first of thunderstorms, and ultimately of cyclones.

Typical tornadoes are commonly supposed to be confined to North America. This is only true to the extent that they are undoubtedly more frequent and probably more violent there than elsewhere. Australian experience provides many genuine examples, but owing to the sparse population and the character of the storms themselves they have not yet been the subjects of very accurate scientific observation.

Judging by the records available, New South Wales and Victoria appear to be the States most liable to these visitations. In New South Wales they are most frequent in the summer, occurring only in connexion with monsoonal depressions; in Victoria they seem quite as liable to occur in connexion with strong Antarctic low-pressure systems, and the numbers do not therefore show the same marked preferences for the summer season.

The conditions most favorable for tornadoes inland and in the summer are—(1) high temperatures; (2) considerable humidity; (3) very small barometric gradient, to which may be added a very probable fourth factor, unusually steep vertical temperature gradient. These seem to be most frequently provided by extensive but comparatively shallow monsoonal depressions, which favour a wide gentle air flow southerly from the tropical interior.

The weather charts for 25th to 29th September, 1911, show conditions typically favorable and abundantly justified by results, inasmuch as two tornadoes resulted. The first was in Victoria at Marong, near Bendigo, on the afternoon of the 27th September, 1911. This supplied all the characteristic features of a tornado, the long inverted cone depending from the dense blue-black thunder cloud, the narrow track, 5 to 12 chains wide and 12 miles in length, along which indescribable damage was wrought, and the accompanying violent thunder and hail storms. Fortunately a photograph of the storm cloud with its pendent funnel was secured by a gentleman 3 miles distant, and this has been reproduced, together with a full description of the storm, &c., in the 1911 September number of the *Australian Monthly Weather Report.* Two days later the same atmospheric conditions resulted in a similar storm in New South Wales at Cudal, between Forbes and Orange. The results in the latter case were not so serious, as the storm occurred in a sparsely populated area.

The charts given will repay inspection. That of the 25th shows a great valley-like depression extending from the Bight to the Northern Territory, while the axis of a high-pressure system lies north and south over Eastern New South Wales and Queensland. A wide direct southward drift of air in front of the trough is thus secured. The chart of the 27th shows the same features, the very slow eastward movement allowing of steady accumulations of heat and increasing humidity. By the 29th the depression was well over South-eastern New South Wales.

In connection with this disturbance no favorable feature appears to have been wanting. Slight though the barometric gradients were, they had complete control of the atmospheric circulation, the air in front of the trough from cumulus base to cirrus level flowing steadily from points near north. This is always favorable to thunderstorm development, and visual observation was sufficient to show that this case was no exception, the writer, who was in Northern Victoria at the time, making a special note of the abundance day after day of "towering" cumulus and cumulo-nimbus clouds.

From the 1st to the 5th November, 1910, a cyclonic depression with very slight gradients, but influencing enormous areas, was slowly passing from the north-west coast across the continent. During the whole of this period barometric conditions, ideal from a thunderstorm point of view, prevailed over the whole of Eastern Australia. They were, if anything, even more favorable than in the preceding example, and of much wider scope. In addition to heavy thunderstorm rains over the greater part of the interior the following exceptional phenomena were reported. At Hergott Springs (S.A.), in the driest part of the continent, a "cyclone" accompanied by a violent thunderstorm passed over the township at 5 p.m. on the 4th instant. This wrecked one house, unroofed others, and threatened loss of life. The

barometer fell extraordinarily—to 28·40 inches—but the value of the reading is unknown. On the same afternoon at Richmond (Q.), 800 miles away, a "terrific cyclone" damaged most of the buildings, derailed railway trucks, and bent double iron telegraph poles. Two inches of rain fell.

On the preceding afternoon, near Laverton (W.A.), a thunder and hail storm, giving half-an-inch of rain, was accompanied by a "hurricane."

Though violent, the foregoing are not absolutely identifiable as tornadoes, but the observer's description of a storm next day at Gemville, a place in the dry north-western interior of New South Wales, leaves little room for doubt. The 5th, he said, will long be remembered. One inch of rain fell in half an hour, hail stripped the ground bare, and a "cyclone," the spiral motion of which was a feature, cut a track through the scrub several miles long. The thunder and lightning were very severe.

The description of a local storm of extreme severity and destructiveness in North-eastern Victoria is of interest, and shows that tornadoes or very similar phenomena may occur under other than summer conditions of heat, humidity, and barometric pressure. About 3 a.m. on the 16th July, 1904, near Avenel, a "fierce wind" swept from N.W. to S.E. over a strip of country about 2 miles long and 30 yards wide. It completely wrecked a farmhouse which lay in its track, killing two of its inmates, carried large pieces of furniture for over half-a-mile, tore up trees by the roots and transported them for considerable distances, and demolished all of an orchard over which it passed. The storm was immediately preceded by vivid lightning and heavy peals of thunder.

The weather charts of the 15th and 16th July show that this occurred in connexion with the final stages of a very intense Antarctic low-pressure system which had been moving slowly eastwards along the south coast-line for five days previously, and suggest that it was coincident with a sudden rise in barometric pressure which ended the "Antarctic" and introduced anticyclonic conditions. The passage of a low-pressure trough usually coincides with a maximum of atmospheric instability, and in this case it seems probable that the exceptional energy developed was in some way connected with the arrival of the colder and denser air of the anticyclonic front—possibly by this causing forced ascent of the warmer and moister air of the low-pressure system. But whichever was cause or whichever effect, we know by experience that a sudden change from cyclonic to anticyclonic conditions, as shown by a large rise in barometers at the end of a lengthy period of Antarctic low pressures, is almost invariably associated with violent atmospheric disturbances and not infrequently thunder and hail storms.

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By Authority : ALBERT J. MULLETT, Government Printer, Melbourne.